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Revision A

Fluids and Combustion Facility Document

ELECTRICAL POWER CONTROL UNIT SPECIFICATION

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Approved by Robert Corban, FCF Deputy Project Manager, Microgravity Science Division, 6700

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NASA - Glenn Research Center
Cleveland, OH 44135

Signature Page

(Official signatures on file with the FCF Project Control Specialist)

Prepared By:

Ted Tin
System Engineer
Glenn Research Center

Reviewed By:

Mark Poljak
System Architect
Glenn Research Center

Concurred By:

Dennis W. Rohn
FCF Chief Engineer
Glenn Research Center

Approved By:

Robert Corban
FCF Deputy Project Manager
Glenn Research Center

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1.0 SCOPE

This specification establishes the performance, design, test, manufacture and acceptance requirements for the Electrical Power Control Unit (EPCU) critical item. This specification has been prepared per the requirements of a type C2A, Critical Item Product Function Specification per SSP41171A.

2.0 REFERENCES

2.1 Applicable Documents

The documents below apply to the design of the EPCU to the extent specified herein. They can also be found in Appendix A. Additional documents are referenced in these documents and can be found in section 2.2 Reference Documents.

Document Number	Document Title
311-INST-001	Goddard Space Flight Center Instructions
67211EFDE101	EPCU Panel Layout (drawing)
FCF-SPEC-001	System Specification International Space Station Fluids and Combustion Facility
LMI 8070.2	Environmental Design and Test Standards for Space Flight Hardware
MIL-STD-1553B	Digital Time Division Command/Response Multiplex Data Bus
NASA-STD-6001	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures For Material In Environments That Support Combustion
NHB 6000.1	Requirements for Packaging Handling and Transportation for Aeronautical and Space Systems, Equipment and Associated Components
NSTS SN-C-0005	Contamination Control Requirements
PPL-21	Goddard Space Flight Center's Preferred Parts List
SSP 30237	Space Station Electromagnetic Emission And Susceptibility Requirements
SSP 30238	Space Station Electromagnetic Techniques
SSP 30243	Space Station Requirements for Electromagnetic Compatibility
SSP 30423	Space Station Approved Electrical, Electronic, and Electromechanical Parts List
SSP 30482	Electric Power Specifications and Standards V1 EPS Electrical Performance Specifications
SSP 52005	ISS Payload Flight Equipment and Guidelines For Safety Critical Structures
SSP 57000	Pressurized Payloads Interface Requirements Document International Space Station
SSP 57001	Pressurized Payloads Hardware Interface Control Document Template International Space Station
SSP 57217	Fluids and Combustion Facility (FCF) Combustion Integrated Rack (CIR) Hardware Interface Control Document International Space Station
SSP30240	Space Station Grounding Requirements International Space Station
SSP30512	Space Station Ionizing Radiation Design Environment

Document Number	Document Title
SSP30573	Space Station Program Fluid Procurement and Use Control Specification
SSP41017	Rack to Mini Pressurized Logistics Module Interface Control Document (ICD) Part 1 International Space Station
SSP50005	Space Station Flight Crew Integration Standard Requirements
TA-92-038	Protection of Payload Electrical Power Circuits
TM-102179	Selection of Wires and Circuit Protective Devices for STS Orbiter Vehicle Payload Electrical Circuits

2.2 Reference Documents

Reference documents are those documents that, though not a part of this document, serve to clarify the intent and contents of this document.

Document Number	Document Title
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment
MSFC-HDBK-527/NSTS 09604	Materials Selection List for Space Hardware Systems
NSTS 13830	Payload Safety Review and Data Submittal Requirements For Payloads Using the: - Space Shuttle International Space Station
TRS1129	Hamilton Sunstrand Test Specification

2.3 Precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supercedes applicable laws and regulations unless a specific exemption has been obtained.

2.4 Acronyms

Acronym	Definition
AC	Alternating Current
Amp	Ampere
APM	Attached Pressurized Module
CAM	Centrifuge Accommodations Module
CDMS	Command Data Management System
CDR	Critical Design Review
CIL	Critical Items List
CIR	Combustion Integrated Rack
dB	Decibels
DC	Direct Current
ECN	Engineering Change Notice
EEE	Electrical, Electronic and Electrochemical
EMI	Electromagnetic Interference
EMC	Electromagnetic Compatibility
EPCU	Electrical Power Control Unit
EPS	Electrical Performance Specifications
ESD	Electrostatic Discharge
FCF	Fluids and Combustion Facility

Acronym	Definition
FDIR	Failure Detection, Isolation, and Recovery
FMEA	Failure Modes and Effects Analysis
FRPCM	Flexible Remote Power Controller Module
GFE	Government Furnished Equipment
GRC	Glenn Research Center
Hz	Hertz
ICD	Interface Control Document
IOP	Input/Output Processor
IP	Internal Position
ISPR	International Space Payload Rack
ISS	International Space Station
IVA	Intra Vehicular Activity
kpa	Kilopascals
kW	Kilowatt
LED	Light Emitting Diode
LET	Linear Energy Transfer
MEFL	Maximum Expected Flight
MEFLE	Maximum Expected Flight Environment
MHz	Megahertz
Mil	Military
MIUL	Material Identification Usage List
MPLM	Mini Pressurized Logistics Module
MTBF	Mean Time Between Failure
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NSPAR	Non-Standard Part Approval Request
NVR	No Verification Required
ORU	Orbital Replacement Unit
PIL	Parts Identification List
PDR	Preliminary Design Review
psia	Pounds per Square Inch Absolute
PSRP	Payload Safety Review Panel
PUR	power-up-restart
QD	Quick Disconnect
RAM	Random Access Memory
RBD	Reliability Block Diagram
RMSA	Rack Maintenance Switch Assembly
RPC	Remote Power Controller
RPCM	Remote Power Controller Module
ROM	Read Only Memory
SARGE	Standard Assurance Requirements and Guidelines for Experiments
SEE	Single Event Effect
SOW	Statement of Work
TBD	To Be Determined
TCS	Thermal Control System
TM	Technical Memo
UIP	Utility Interface Panel
UOP	Utility Outlet Panel
VC-S	Visible Clean-Sensitive
Vdc	Voltage direct current
Vrms	Volts Root-Mean-Square

3.0 REQUIREMENTS

3.1 EPCU Definition

The EPCU is a key element of the FCF electrical power system. All electrical power entering the FCF from the International Space Station (ISS) electrical power system is controlled by the EPCU. The EPCU shall provide 3 kilowatt (kW) of 120 voltage direct current (Vdc) to 28 Vdc bulk power conversion, 2.9 kW of unprocessed but protected power at 120 Vdc, 6 fault protected power circuits of 120 Vdc, 48 fault protected power circuits of 28 Vdc, coordinated prioritized load shedding of all power output circuits, power bus transfer capability for all loads, and isolated dynamic power sharing capability between two ISS electrical power busses. All power output circuits are configured by the load for paralleling of power output circuits. The EPCU interfaces with the FCF Command Data Management System (CDMS) via 1553B interface bus.

3.1.1 Interface Definition

3.1.1.1 Electrical

Interfaces are established through electrical connectors located on the front and rear panels of the EPCU. The EPCU will receive 120 Vdc power from connectors located at interface B at the Utility Interface Panel (UIP). Interface B is defined in SSP 57000 section 3.2. An On/Off inhibit function is also established via connector on the rear panel. Output power 120 Vdc is provided via two connectors on the rear panel. 28 Vdc output power is provided via 12 connectors on the front panel.

3.1.1.2 Mechanical

The EPCU is mounted in an International Space Payload Rack (ISPR). The EPCU design accommodates the electrical and coolant connections at the front and rear of the housing. Mounting to the rack is accomplished through a rail system that attaches to EPCU at the front and rear lower corners of the unit.

3.1.1.3 Thermal

Interfaces to the Thermal Control System (TCS) are to be made through an EPCU internal coolant passage to rack coolant system via connectors located on the rear panel.

3.1.1.4 Data BUS Interface

The EPCU is controlled via 1553 bus by the Input Output Processor (IOP) in the FCF rack. The connectors for this function is located on the rear panel.

3.2 Characteristics

3.2.1 Performance Characteristics

3.2.1.1 Electrical Power Characteristics

The EPCUs configured for FCF are connected to the ISS utilizing the ISS Interface B at the User Interface Panel (UIP) in the US Lab Module as the power source. The EPCUs shall be compatible with the prescribed characteristics of the Electrical Power System (EPS) defined in SSP 57000 section 3.2 and will not produce an unsafe condition or one that could result in damage to ISS equipment of payload hardware.

3.2.1.2 Steady State Voltage Characteristics

3.2.1.2.1 Interface B

The EPCU shall operate from Interface B with a steady state voltage limit of 116 to 126 Vdc.

3.2.1.3 Ripple Voltage Characteristics

3.2.1.3.1 Ripple Voltage and Noise

The EPCU shall operate as specified when subjected to the input time domain ripple and voltage noise level of 2.5 Vrms maximum from 30 Hz to 10 KHz.

3.2.1.3.2 Ripple Voltage Spectrum

The EPCU shall operate as specified when subject to the input ripple voltage spectrum as shown figure 1.

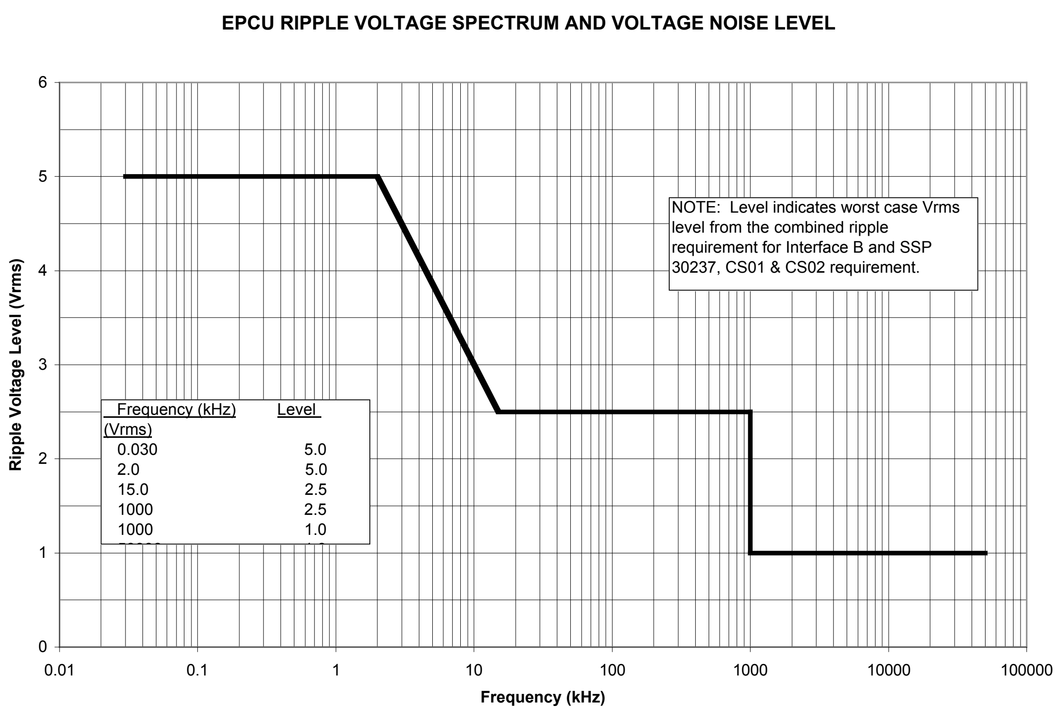


Figure 1. Ripple Voltage Spectrum for Interface B

3.2.1.4 Transient Voltages

The EPCU shall operate without sustaining loss of function or permanent damage as a result of Interface B transient characteristics and be compatible with the limits of magnitude and duration for the voltage transients that occur within the transient envelope at interface B as shown in Figure 2.

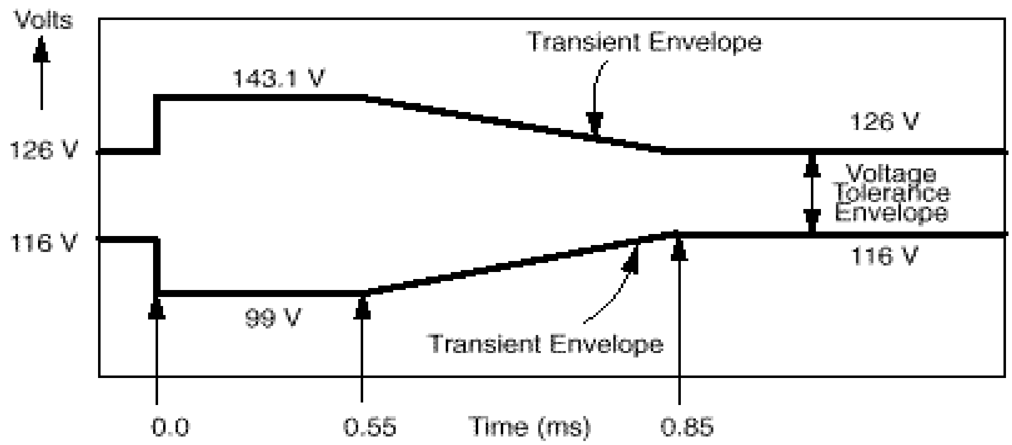


Figure 2. Interface B Voltage Transients

3.2.1.5 Fault Clearing and Protection

The EPCU connected to Interface B shall be safe and not suffer damage with the transient voltage conditions that are within the limits shown in Figure 3. The limits for these transient conditions are including a peak of 369 Vdc for 12 microseconds, 200 Vdc for 150 usec, and 156 Vdc for 138 usec. Used one ohm as the suggested source impedance.

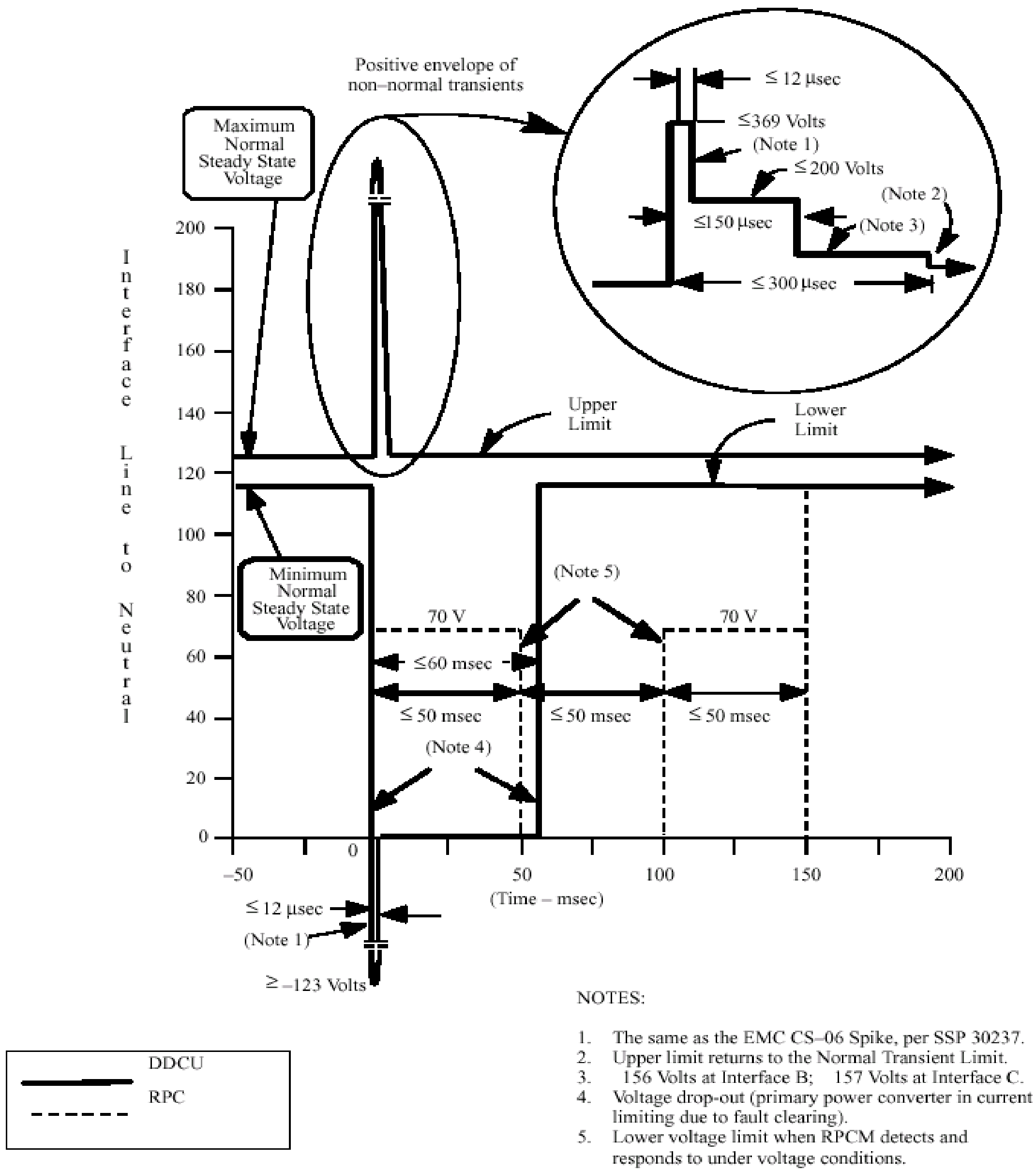


Figure 3. Fault Clearing and Protection Transient Limits

3.2.1.6 Non-Normal Voltage Range

The EPCU connected to Interface B shall not produce an unsafe condition or that could result in damage to ISS equipment or payload hardware with the following non-normal voltage. Non normal overvoltage condition will not exceed 165 Vdc for 10 seconds. On undervoltage conditions, the US standard Remote Power Controller Module (RPCM) will undervoltage trip if the voltage remains below 102 Vdc for 50 milliseconds.

3.2.1.7 Deleted

3.2.1.8 Power BUS Isolation

The EPCU shall provide a minimum of 2 megohm isolation in parallel with no more than 0.001 microfarads of mutual capacitance between two independent ISS power buses connected to the EPCU. Mutual capacitance is defined as line-to-line capacitance, exclusive of the EMI input filter. This isolation shall be two faults tolerant and no single EPCU failure shall cause cross coupling between the two independent ISS power buses. Diodes shall not be used to electrically tie together two independent ISS power buses. This requirement applies to both supply and return lines.

3.2.1.9 Compatibility With Soft Start/Stop RPC

The EPCU connected to Interface B shall be compatible with ISS RPCM soft start/stop characteristics shown in figure 4. The EPCU shall initialize with soft start/stop performance characteristics when power is applied, sustained and removed by control of the remote power control switches. The soft start/stop function, active only when the Remote Power Controller (RPC) is commanded on or off, is limited to 100 amps/ms or less by the RPC output. The response of the soft start/stop function is linear for 1 to 10 ms.

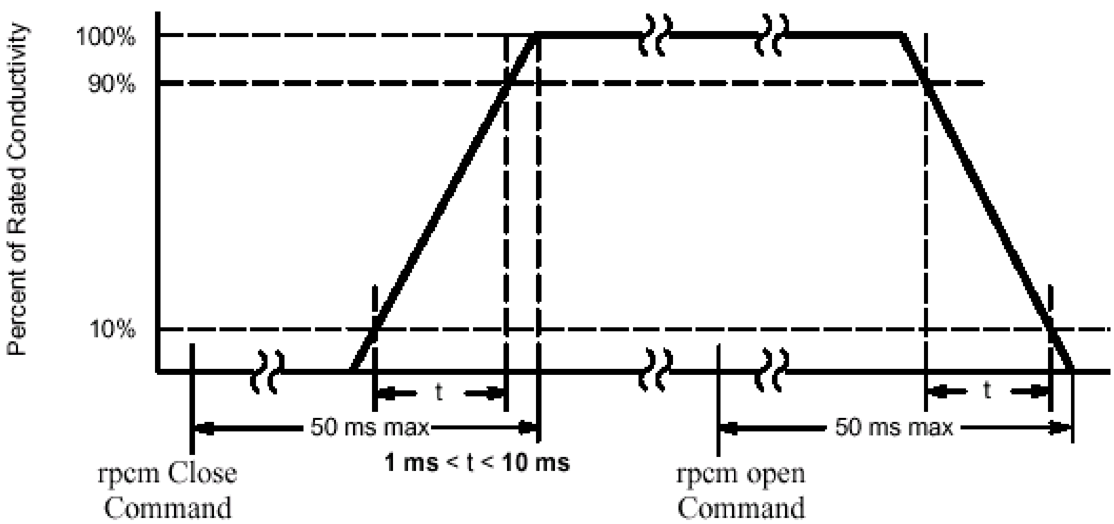
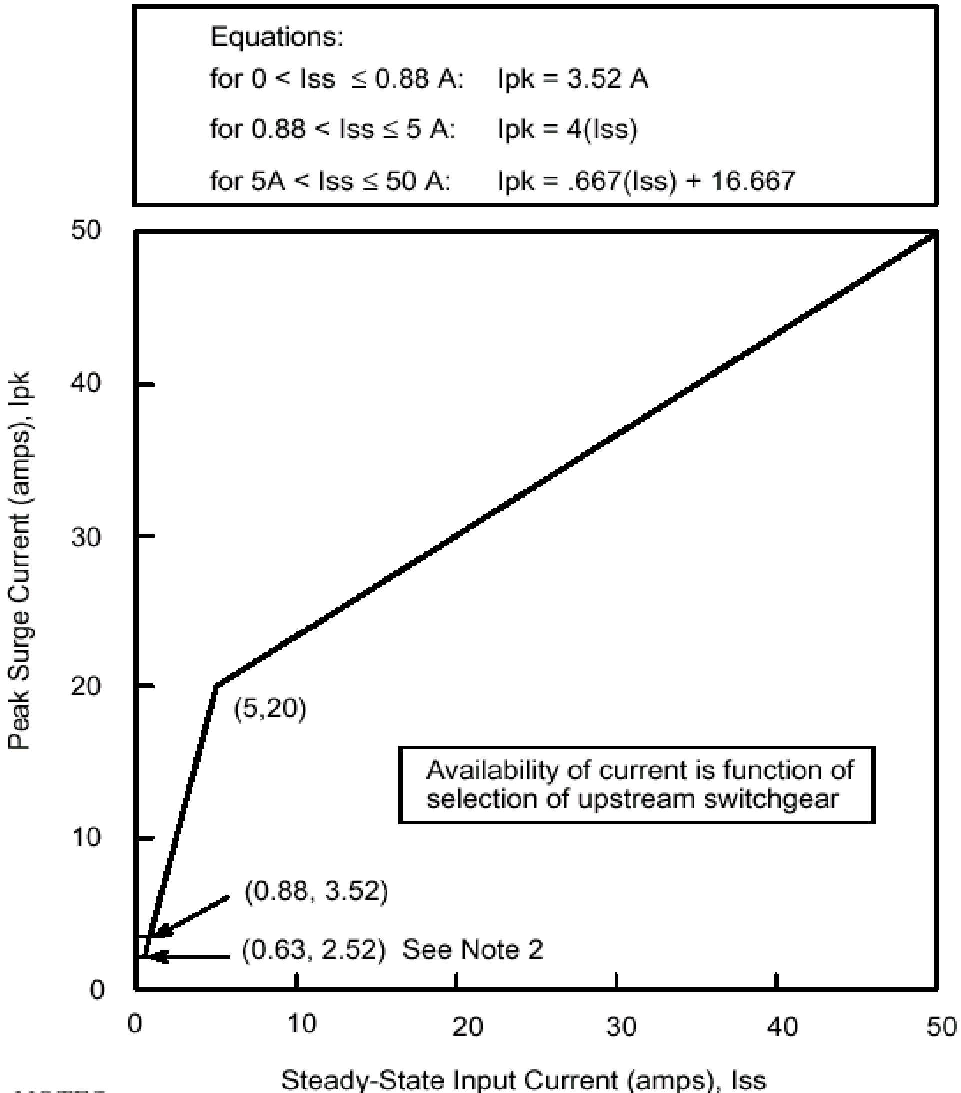


Figure 4. U.S. RPCM Soft Start/Stop Characteristics

3.2.1.10 Surge Current

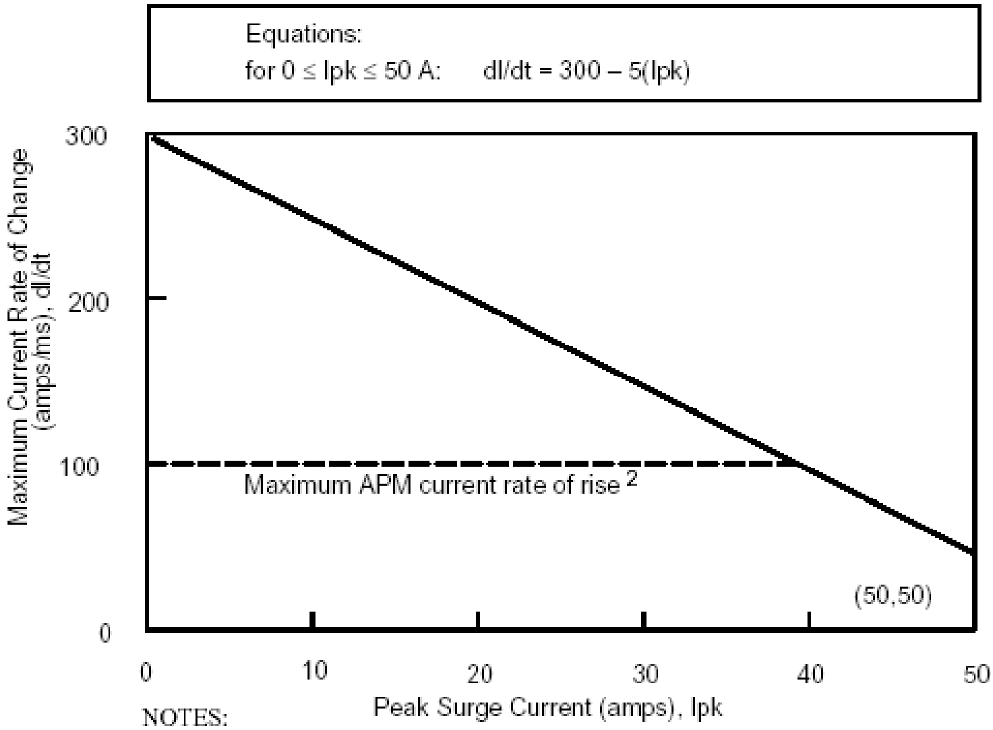
The EPCU connected to Interface B shall exhibit surge current characteristics at the power inputs that do not exceed the surge current values defined in Figures 5 and 6 when powered from a voltage source with characteristics specified in paragraphs 3.2.1.1 “Electrical Power Characteristics” and 3.2.1.9 “Compatibility with Soft Start/Stop RPC”, with the exception that the source impedance is considered to be 0.1 ohm. The duration of the surge current shall not exceed 10 ms. These requirements apply to all operating modes and changes including power-up and power-down.



NOTES:

1. For transients less than 100 microseconds, refer to SSP 30237.
2. NASA Space Station equipment accommodated in JEM will have a maximum allowable peak surge current of 2.52 amps for equipment having a steady-state input no greater than 0.63 amps.

Figure 5. Peak Surge Current Amplitude vs. Steady State Input Current



NOTES:

1. For transients less than 100 microseconds, refer to SSP 30237.

Figure 6. Maximum Current Rate of Change vs. Peak Surge Current Amplitude

3.2.1.11 Reverse Energy Current

The EPCU shall comply with the requirements defined in Table I for the reverse energy/current into the upstream power source. The EPCU in it's integrated rack configuration shall meet either the reverse energy or the reverse current requirement for all conditions specified in Table I when powered from a voltage source with characteristics specified in paragraphs 3.2.1.1 and 3.2.1.9 with a source impedance of 0.1 ohm.

ISPR INTERFACE Power/RPCM Type	MAXIMUM REVERSE ENERGY (Joules)	MAXIMUM REVERSE CURRENT (amps)		
		Pulse t < 10 μs	**Peak t < 1 ms**	**Steady State t > 1 s**
3 kW/ type VI	3.0	400	250	3
6 kW/ type III	6.0	800	500	6

μs = microseconds ms = milliseconds s = second

Table I. Maximum Reverse Energy/Current From Downstream Loads

3.2.1.12 Remote Power Controllers (RPCs)

The EPCU connected to Interface B shall operate and be compatible with the RPCM characteristics described below. Table II defines the characteristics of the remote power controllers. Over current protection is required at all points in the system where power is distributed to lower level or feeder or branch lines.

PWR INTERFACE	MAIN PWR FEEDER			AUX PWR FEEDER	
	LOWEST CURRENT LIMITATION LEVEL	MINIMUM TRIP THRESHOLD	MINIMUM* TRIP DECISION TIME	LOWEST CURRENT LIMITATION LEVEL	MINIMUM* TRIP DECISION TIME
3 kW ISPR					
APM	35.0 A	N/A	1.5 ms	26.1 A**	1.5
JEM	(1)	N/A	(1)	(3)	(3)
USL	N/A	27.5	40 ms	13.2 A	31 ms
6 kW ISPR					
APM	72 A	N/A	1.5 ms	26.1 A**	1.5
JEM	(2)	N/A	(2)	(3)	(3)
USL	N/A	55 A	40 ms	13.2 A	31 ms
12 kW ISPR					
USL FEED A	N/A	55 A	40 ms	N/A	N/A
FEED B	N/A	55 A	40 ms	N/A	N/A

*** Trip decision time at or above limiting/trip threshold.**
**** Attached Pressurized Module (APM) Racks O1 and O2: 18A**

Table II. Detailed Upstream Protection Characteristics

U.S. Lab/CAM (Centrifuge Accommodations Module): ISPR locations are connected to non–current limiting RPCs for 3 and 6 kW feeds, and to current limiting RPCs for 1.44 kW (Auxiliary) feeds. Nominal current ratings are 25, 50, and 12 amperes respectively. The overload limitation characteristics of the power feeders are defined in Figure 7.

For the non–current limiting RPCs:

- A feeder current above the threshold at 500%–600% of nominal rating for 0 to 10 microseconds will cause the RPC to trip.
- A feeder current above the threshold at 190%–210% of nominal rating for 1 to 2 milliseconds will cause the RPC to trip.
- A feeder current above the threshold at 110%–120% of nominal rating for 40 to 48 milliseconds will cause the RPC to trip.

For the current limiting RPCs on the 1.44 kW feeds:

- The current will be controlled to within the limiting level of 13.2 to 14.4 amperes within 1 millisecond. The RPC will trip if the current remains in the limiting region up to the decision time of 34.5 ± 3.5 milliseconds

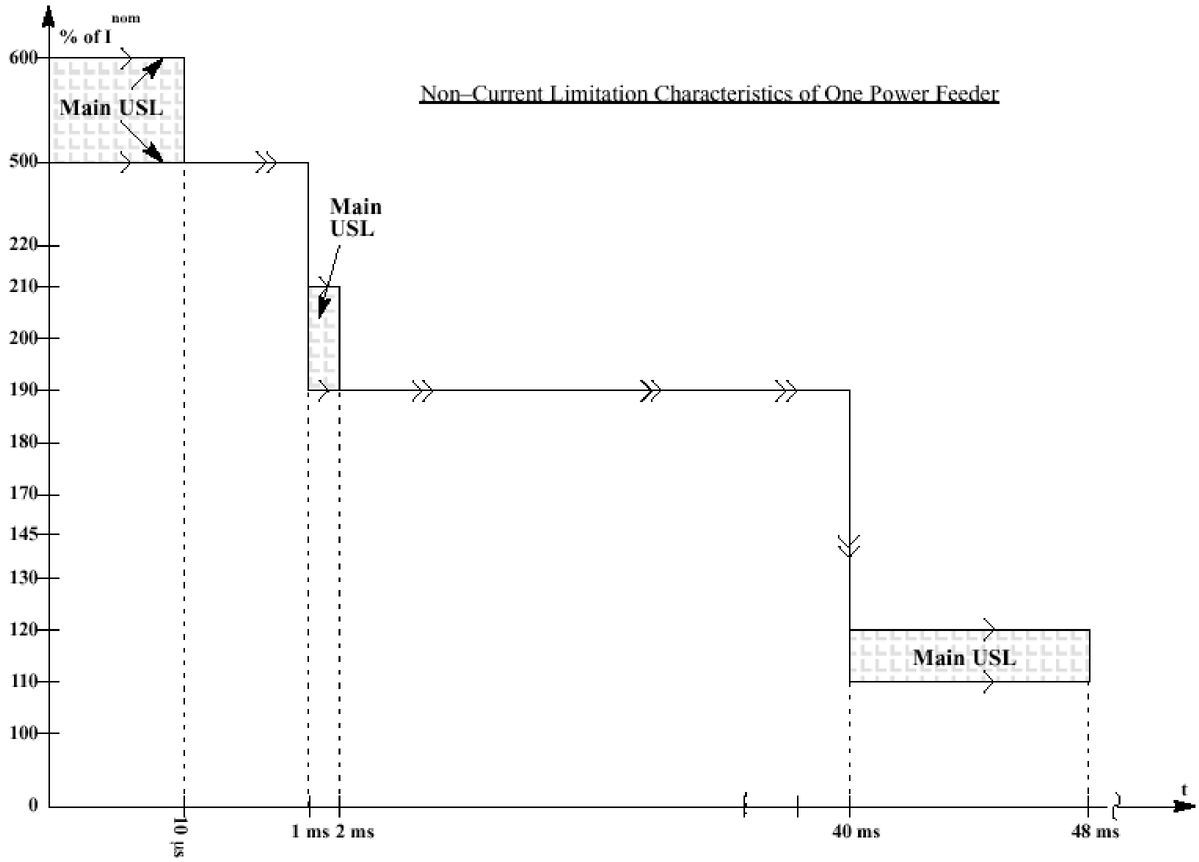


Figure 7. Non-Current Limitation Characteristics of One Power Feeder

3.2.1.13 RPC Trip Coordination

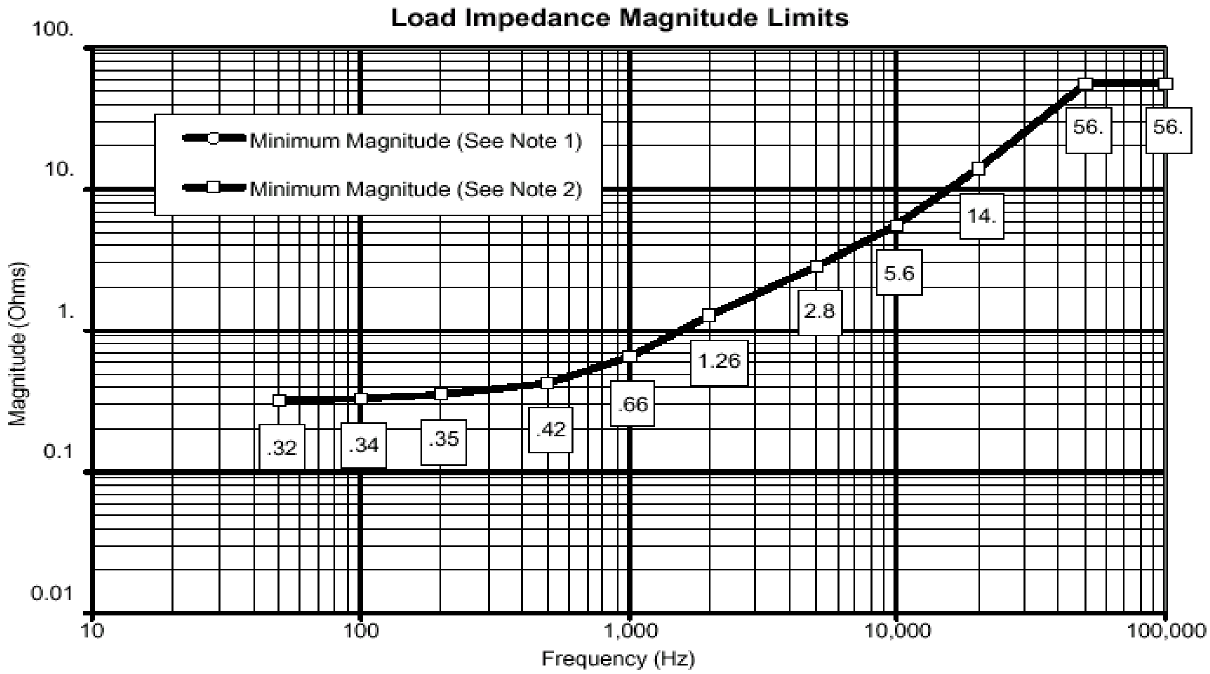
3.2.1.13.1 Payload Trip Ratings

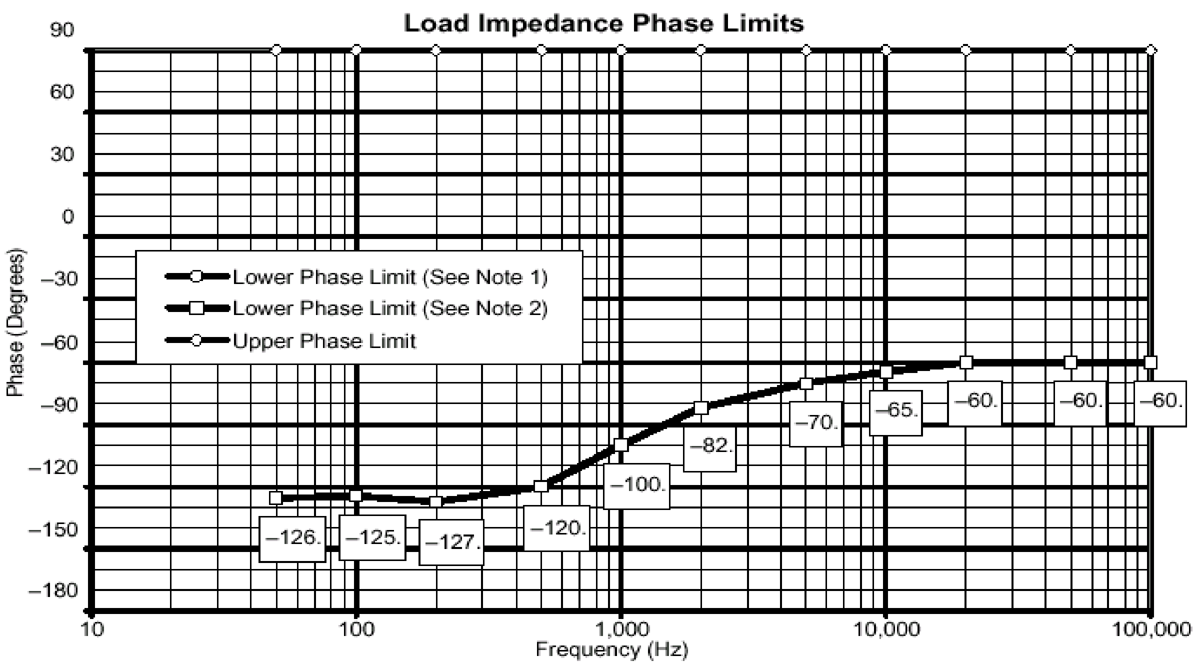
The EPCU circuit protection device trip ratings shall be coordinated with the upstream RPC trip characteristics in table II so that an event that activates the protection in a downstream device will not also trip the one upstream.

3.2.1.14 EPCU Input Impedances

3.2.1.14.1 Interface B

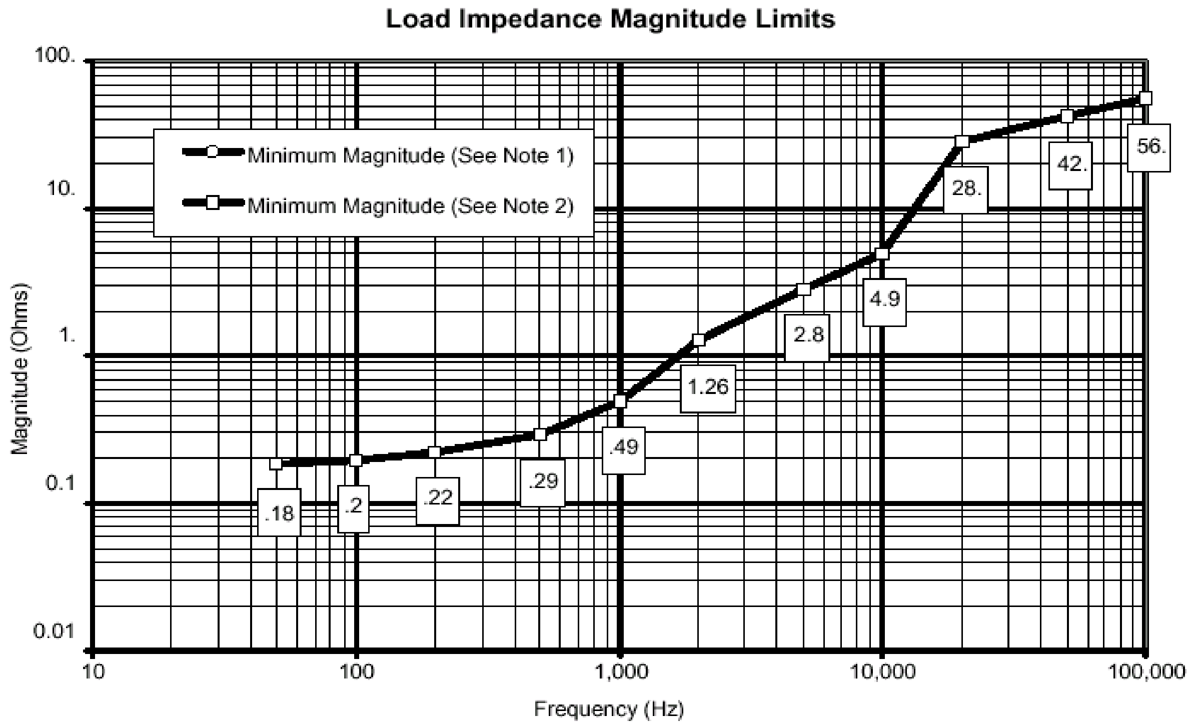
The input impedance presented by the EPCU to the Interface B shall not exceed the bounds defined in Figures 8 and 9 for input over the frequency range of 50Hz to 100 kilohertz (kHz). The magnitude component of the input impedance presented by the EPCU shall not be less than the minimum defined in Figures 8 and 9. At frequencies where the magnitude component of the input impedance presented by the EPCU is less than the defined minimum, the phase component of the impedance shall not exceed the bounds defined in these Figures.

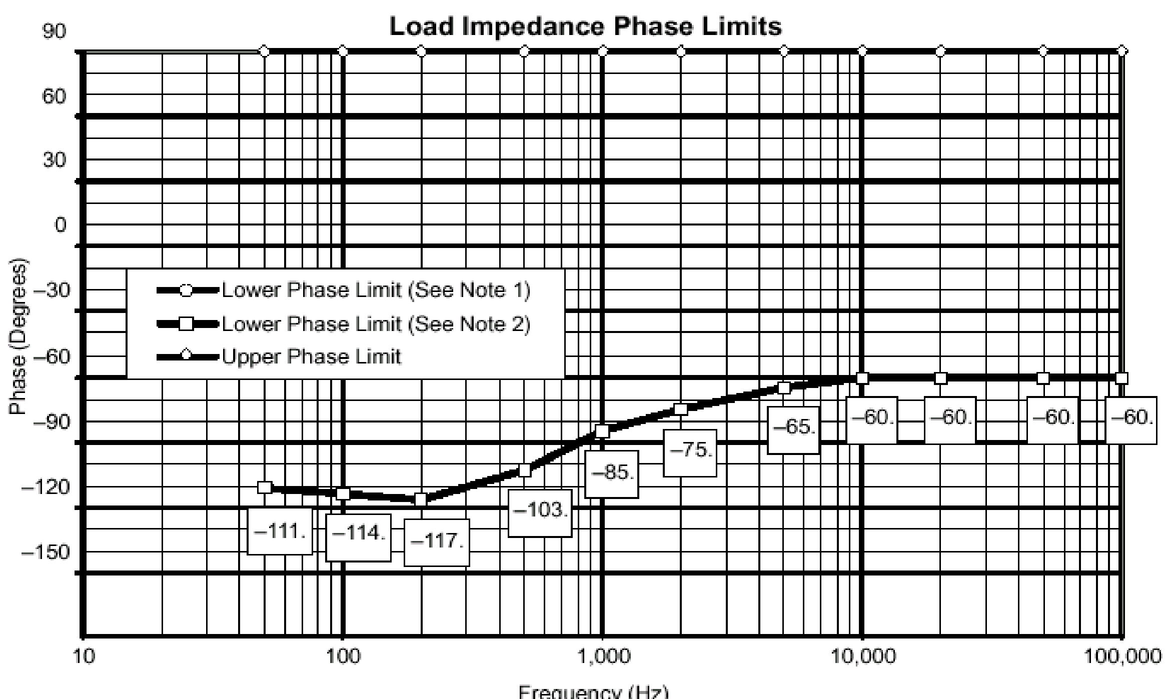




Notes:
1. Limit when total load on the Secondary Power Source is less than 400 watts.
2. Limit when total load on the Secondary Power Source is at least 400 watts.

Figure 8. 3 kW Interface B Load Impedance Limits





Notes:
1. Limit when total load on the Secondary Power Source is less than 400 watts.
2. Limit when total load on the Secondary Power Source is at least 400 watts.

Figure 9. 6 kW Interface B Load Impedance limits

3.2.1.15 Large Signal Stability

The EPCU connected to Interface B shall maintain stability with the ISS EPS interface by damping a transient response to 10 percent of the maximum response amplitude within 1.0 millisecond (ms), and remaining below 10 percent there after under the following conditions:

1. The rise time/fall time (between 10 and 90 percent of the amplitude) of the input voltage pulse is less than 10 microseconds (s).

2. The voltage pulse is to be varied from 100 to 150 microseconds in duration.

Note: Figure 10 is used to clarify the above requirement.

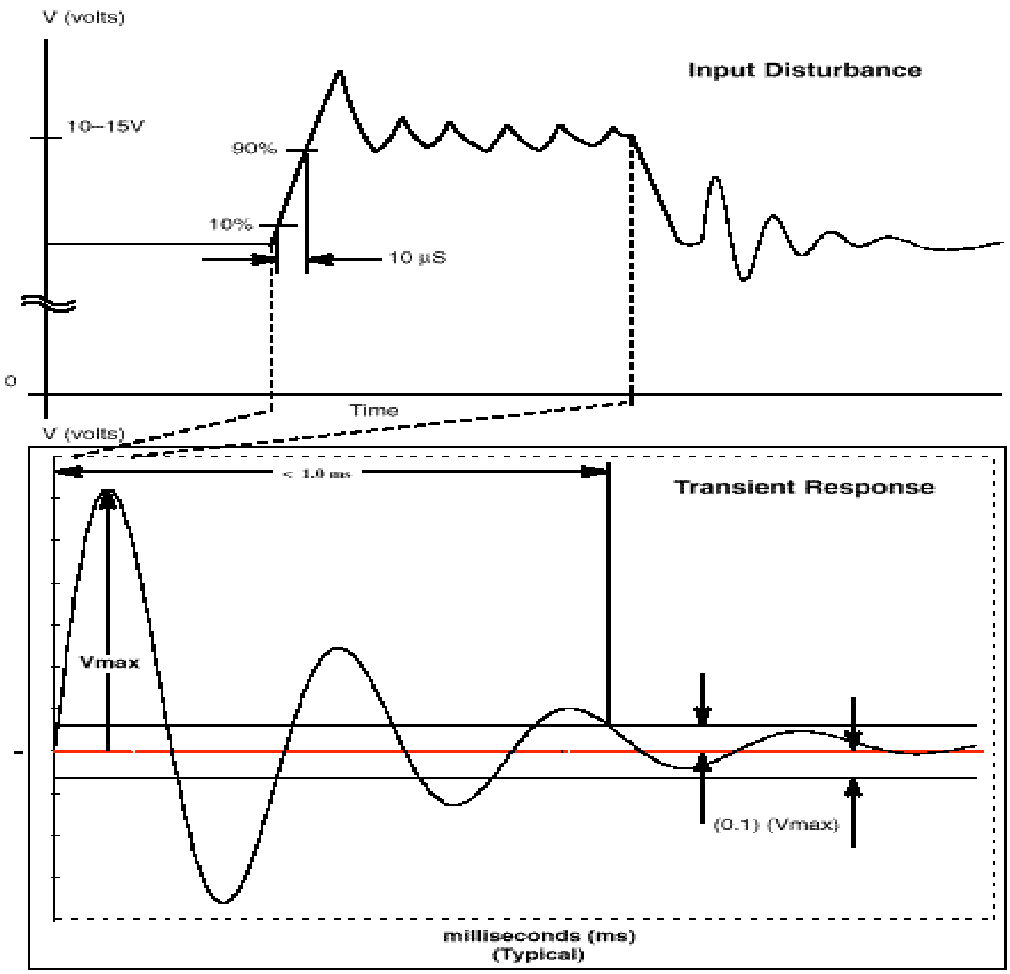


Figure 10. Pulse Applied to Power Input of the EPCU

3.2.1.16 Maximum Ripple Voltage Emissions

Maximum ripple voltage induced on the input power line by the EPCU connected to Interface B shall be no greater than 0.5 V peak-to-peak.

3.2.1.17 Electrical Load-Stand Alone Stability

The EPCU connected to Interface B shall be considered locally stable by meeting the following requirements:

- Paragraph 3.2.2.1 of SSP 30237 (CS01)
- Paragraph 3.2.2.2 of SSP 30237 (CS02)
- Paragraph 3.2.2.3 of SSP 30207 (CS06)

3.2.1.18 EPCU Output Characteristics

3.2.1.18.1 Wire Derating

- Derating criteria for EPCU shall be per NASA Technical Memo (TM) 102179 as interpreted by NSTS 18798, TA-92-038.
- 4 gauge wire shall be used for main and auxiliary power connections at the UIP.

3.2.1.18.2 Loss of Power

The EPCU shall fail safe in the event of a total or partial loss of power.

3.2.1.18.3 EPCU User Parameters

The EPCU user shall obtain 28 Vdc power from 12 connectors with 4 – 4 amp circuits on the front panel and 120 Vdc from 2 connectors with 3 – 4 amp circuits on the rear panel.

3.2.1.18.4 Power Quality

3.2.1.18.4.1 Output Voltage Range

The output voltage range for 28 Vdc shall be 27.0 Vdc to 29.0 Vdc.

The output voltage range for 120 Vdc shall be 118 Vdc to 120 Vdc when the EPCU input voltage is 120 Vdc.

3.2.1.18.4.2 Ripple

Ripple for 28 Vdc shall be 0.5 volts peak-to-peak maximum.

3.2.1.18.4.3 Transients

Transients for 28 Vdc shall be within the range of 20 to 35 volts and recover within 1 millisecond for any load change within the rating of the EPCU converters.

3.2.1.18.4.4 Current Limiting and Trip Function

If an overload is applied to the EPCU output, the current shall be limited to a value of 4.2 to 4.6A for each channel connected to the load. The trip time shall be dependent on the load impedance and the corresponding voltage drop across the switch. The trip characteristic for each output is shown in Figure 11. This trip characteristic applies to both 28V and 120V outputs of the EPCU. For a short circuit, the trip time will be about 0.1 second for the 120 Vdc and 0.7 second for the 28 Vdc output.

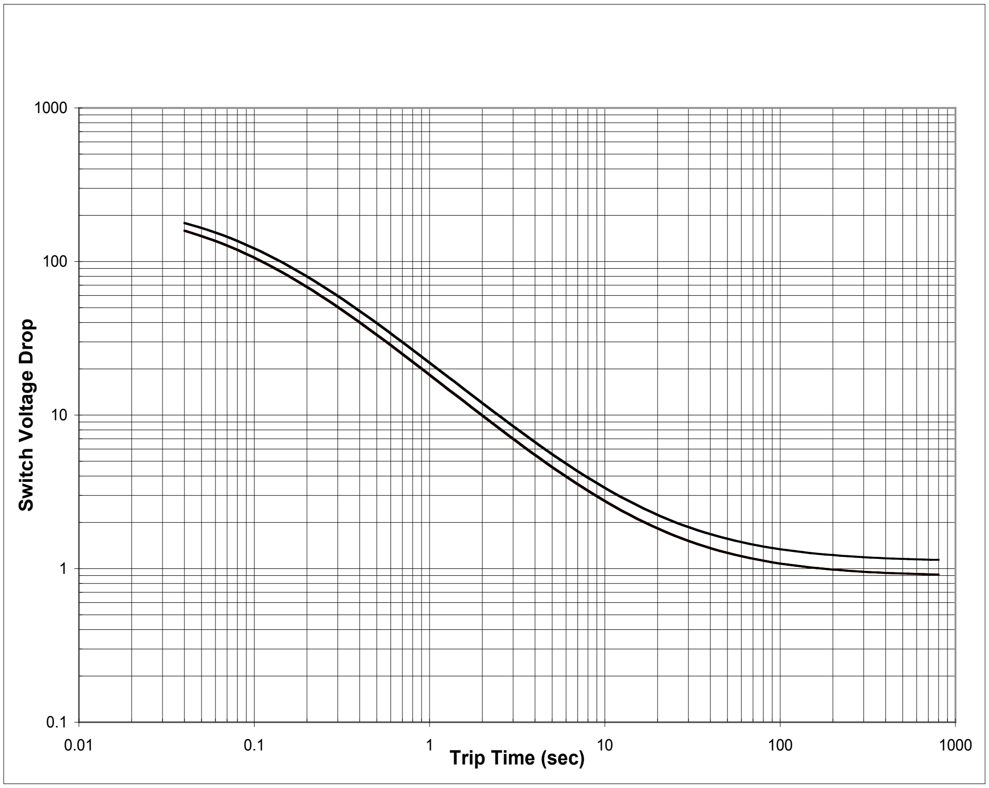


Figure 11. Solid State Current Limit Switch Trip Characteristic

3.2.1.18.4.5 Parallel Operation

Parallel operation of the 6 - 120V dc channels and the 48 – 28 Vdc channels to provide current to higher power loads is accomplished through connecting the power and return leads in parallel with each other. Paralleling pins in the connectors must also be connected together. The rating of the output is multiplied by the number of channels paralleled.

3.2.1.18.4.6 Remote Trip Function

Remote tripping of the solid state current limit switches is accomplished by grounding any of the paralleling pins. For 28 Vdc users the ground is available at any of the power return lines. For 120 Vdc users, an isolated return is provided as a separate pin in the connector. See tables III and IV.

28 Vdc Connections

J11 - J22 Pin	Name	Function
A	1 +	Power Out
B	1 -	Power Return
D	2 +	Power Out
E	2 -	Power Return
G	3 +	Power Out
H	3 -	Power Return
K	4 +	Power Out
L	4 -	Power Return
M	P 1	Parallel Jumper
N	P 2	Parallel Jumper
P	P 3	Parallel Jumper
R	P 4	Parallel Jumper
S	I P	Initial Position Jumper

Table III. J11 - J22

120 Vdc Connections

J3 - J4 Pin	Name	Function
A	1+	Power Out
B	1-	Power Return
D	2+	Power Out
E	2-	Power Return
G	3+	Power Out
H	3-	Power Return
M	P 1	Parallel Jumper
N	P 2	Parallel Jumper
P	P 3	Parallel Jumper
S	I P	Initial Position Jumper
C	Return	Jumper Return

Table IV. J3 - J4

3.2.1.18.4.7 Initial Position

The Initial Position (IP) pin in the connector determines the power up state of the first channel in each connector group when power is applied to the EPCU. Left open the state will be off after power is applied, connected to ground the state will be on after power is applied.

3.2.1.19 Health Monitoring Sensor Data

Sufficient sensor data see table V, shall be provided external to the EPCU to allow analysis to determine the health of the solid state current limit switches, power converter (s), and MIL-STD-1553B interface, and to support the Fault Isolation Function. The Fault Isolation function, to be performed in the next higher level controller, will identify internal EPCU failures to provide an ORU (Orbital Replacement Unit) failure status signal to its next higher level controller.

Data Capture: The EPCU shall have the capability of providing the necessary information over the MIL-STD-1553B bus to determine if a solid state current limit switch overload trip was the result of an actual overload (fault) condition or an internal failure of the EPCU (e.g. sensor failure, or sensor conditioning circuitry failure).

3.2.1.20 EPCU Internal Sensors

Instrumentation shall be provided as defined in Table V utilizing data formats defined in 3.2.2.3.4.1.

1	EPCU 120 Volt input Bus A Voltage	200 Vdc
2	EPCU 120 Volt input Bus B Voltage	200 Vdc
3	EPCU main output 28V Bus Voltage	40 Vdc
4	EPCU 120 Volt input Bus A Current	60 Adc
5	EPCU 120 Volt input Bus B Current	60 Adc
6	EPCU 120/28 Volt Converter R output Current	50 Adc
7	EPCU 120/28 Volt Converter S output Current	50 Adc
8	EPCU 120/28 Volt Converter T output Current	50 Adc
9	28 Volt total output Current 1 to all 28 Volt FRPCs	150 Adc
10	28 Volt total output Current 2 to all 28 Volt FRPCs	150 Adc
11	Bus A Converter Share	100 %
12	Coolant Inlet Temperature of EPCU cold plate	500 °K
13	Coolant Outlet Temperature of EPCU cold plate	500 °K
14	EPCU 120 Volt input Bus A negative transient input current	20 Adc
15	EPCU 120 Volt input Bus B negative transient input current	20 Adc
16	5 volt power supply	10 Vdc
17	5 volt power supply	10 Vdc
18	120/28 Volt Converter R temperature	500 °K
19	120/28 Volt Converter S temperature	500 °K
20	120/28 Volt Converter T temperature	500 °K
21	Converter R+S+T Current	200 Adc
22	Main Bus negative transient current	20 Adc
23	Main Bus negative transient current	20 Adc
24	Analog ground	10 Vdc
25	11 Vdc	10 Vdc
26	A1 Motherboard temperature	500 °K
27	A2 Motherboard temperature	500 °K
28	Spare_Ch3 (defaults to $BFFF_H$)	10 Vdc
29	Spare_Ch4 (defaults to $CFFF_H$)	10 Vdc
30	Spare_Ch5 (defaults to $DFFF_H$)	10 Vdc
31	Spare_Ch6 (defaults to $EFFF_H$)	10 Vdc
32	Spare_Ch7 (defaults to $FFFF_H$)	10 Vdc

Table V. EPCU Sensor Data (Analog Data Scaling)

3.2.1.21 Functional Performance

The Fluids/Combustion Facility (FCF) EPCU is a key element of the FCF electrical power system. All electrical power entering the FCF from the International Space Station (ISS) electrical power system goes through, and is controlled by, the EPCU. Each EPCU provides 3 kW of 120 Vdc to 28 Vdc bulk power conversion, 6 fault protected power circuits of 120 Vdc, 48 fault protected power circuits of 28 Vdc, coordinated prioritized load shedding of all power output circuits, power bus transfer capability for all loads, and isolated dynamic power sharing capability between two ISS electrical power buses. All power output circuits are configurable by the load for paralleling of power output circuits. The EPCU is connected to the ISS Thermal Control System (TCS) moderate temperature coolant loop. The EPCU coolant loop may be connected in series with other thermal loads in the FCF. All internal temperature, voltage, and current sensor data is communicated to the FCF CDMS via a redundant 1553B interface bus. Two step commands for setting trip priorities, bus allocations, RPC state, etc. are accomplish through the CDMS via the 1553B interface. A cold plate provides for conductive cooling of all EPCU hardware. A 120 Vdc input solid state current limit switch controls power to all 120 Vdc loads (internal and external with the exception of internal 28 Vdc control power). The input solid state current limit switch can connect 120 Vdc loads to bus A or B. Three converters are connected to a common 28 Vdc power bus which feeds the 28 Vdc output solid state current limit switch. A remote power switch is used to turn the EPCU ON and OFF. All command, data, and status information is passed through a 1553B interface and control assembly. The EPCU internal architecture shall be as shown below.

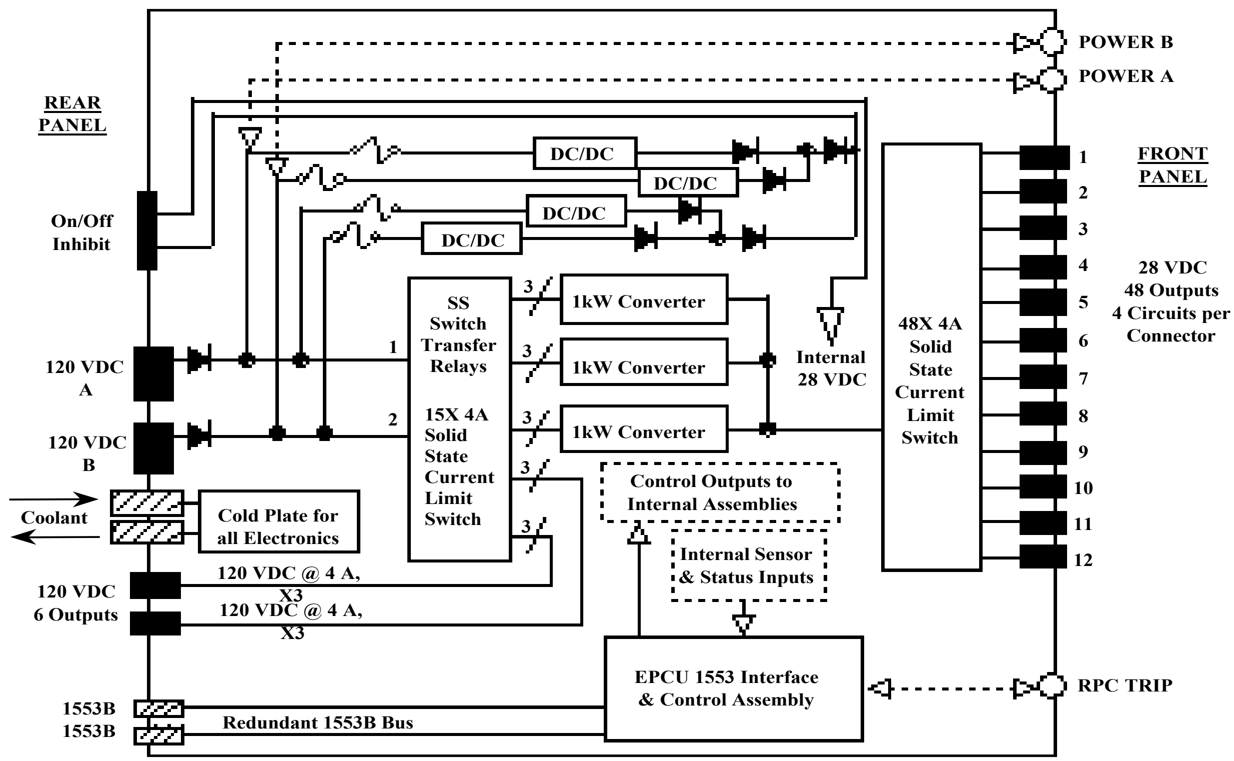


Figure 12 EPCU Block Diagram

3.2.1.22 Load Shedding

A hardware based means using analog or digital circuits internal to the EPCU shall implement a 16 level prioritized load shedding function to assure that the power allocation to the facility on Channel A and Channel B is not exceeded in the event of a rack power feed failure or ISS power bus failure. Priorities shall be set and monitored per the data interface in “EPCU Command Control Interface Characteristics” 3.2.2.3.4.1 Priority shall be a four bit code, 0-15 (F), with zero representing never trip, one representing the highest priority load and fifteen (F) representing the lowest priority load.

3.2.1.23 Failure Detection, Isolation and Recovery

The EPCU shall protect itself from voltages, currents, outside of its normal operating range, and loss of adequate cooling. The transient and abnormal electrical operating limits are specified in the power quality documents. As a minimum, input and output over-voltage and under-voltage protection shall be provided at both the 120 Vdc and 28 Vdc levels, and over-temperature alarm and shutdown functions shall be provided. This function shall not rely on sensors, or logic, external to the EPCU for implementation.

3.2.1.24 Converter Characteristics

Output Power: Each EPCU shall consist of three converter "modules" rated at 1 kW each. Total 28 Vdc output Power rating for the EPCU is 3 kW continuous.

Load Sharing: Each EPCU load converter shall be capable of continuously variable load sharing with other EPCU load converters.

Nominal Input Voltage: 120 Vdc.

Nominal Output Voltage: 28 Vdc.

Transformer Isolation: The DC to DC converter units shall have 1 Megohm minimum of transformer isolation between the 120V input and the 28V output for all operating configurations, including all 3 converters connected to the same input bus.

Current Limit: Current limit value for the power converters shall be between 110 and 150 percent of rated current.

Minimum power converter efficiency from 80% to 100% load shall be 92%.

Minimum power converter efficiency at 50% load shall be 93%.

3.2.1.25 Solid State Current Limit Switch (RPC) Characteristics

The solid state current limit switches shall be suitable for operation in 120 Vdc and 28 Vdc circuits with components optimized for operation at the intended voltage.

Current Limit Range: All solid state current limit switches shall be 4 Amps nominal with current limiting between 4.2 and 4.6 Amps.

Solid state current limit switch Arrangement: A total of 63 solid state current limit switch channels shall be provided, arranged as shown on Figure 12.

120 Vdc Channels: 15 of the solid state current limit switch channels shall be arranged for 120 Vdc channel size at 4 amperes. The converter input solid state current limit switches shall be arranged in 3 groups of 3 to provide 12 amps per group. The two rear panel output connectors shall be arranged in two groups of three circuits. Adjacent channels in each group may be paralleled.

28 Vdc Channels: The remaining (48) channels shall be arranged for 28 Vdc operation at 4 amperes. Adjacent channels in each group may be paralleled.

3.2.1.26 Front Panel Indicators

Indicators: Indicators and displays shall be flush mounted.

All EPCU panel indicators shall be light emitting diodes (LEDs) that shall not require replacement for the life of the EPCU. Any glass used in the LEDs shall be contained within a plastic and metal housing.

3.2.1.26.1 Power A

An illuminated green LED shall indicate presence of power on input bus A. The absence of power shall be indicated by extinguishment of the LED.

3.2.1.26.2 Power B

An illuminated green LED shall indicate presence of power on input bus B. The absence of power shall be indicated by extinguishment of the LED.

3.2.1.26.3 RPC Trip

An illuminated red LED shall indicate that a solid state current limit switch has tripped off due to an overload condition. Nominal operation shall be indicated by extinguishment of the LED.

3.2.2 Physical Characteristics

The EPCU physical architecture shall be as shown in Figure 13.

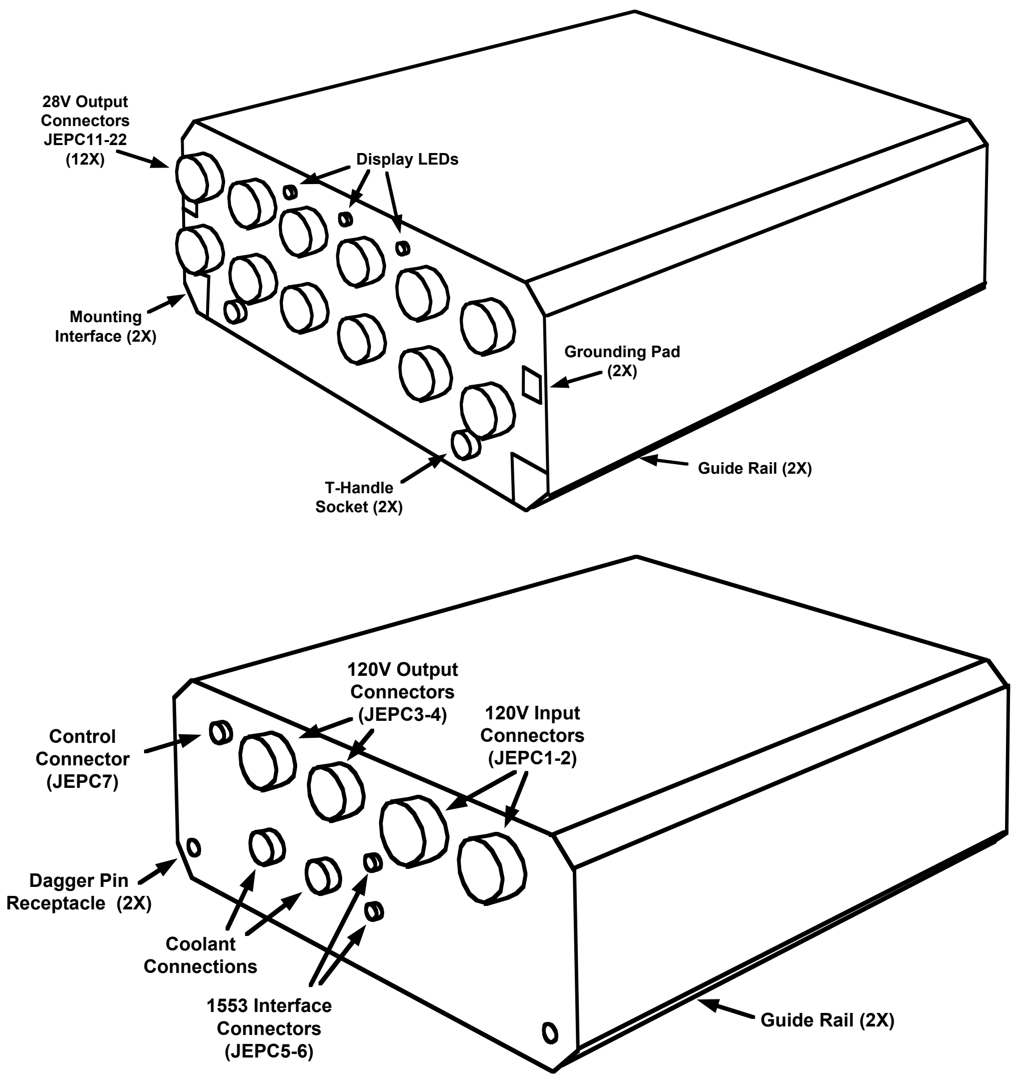


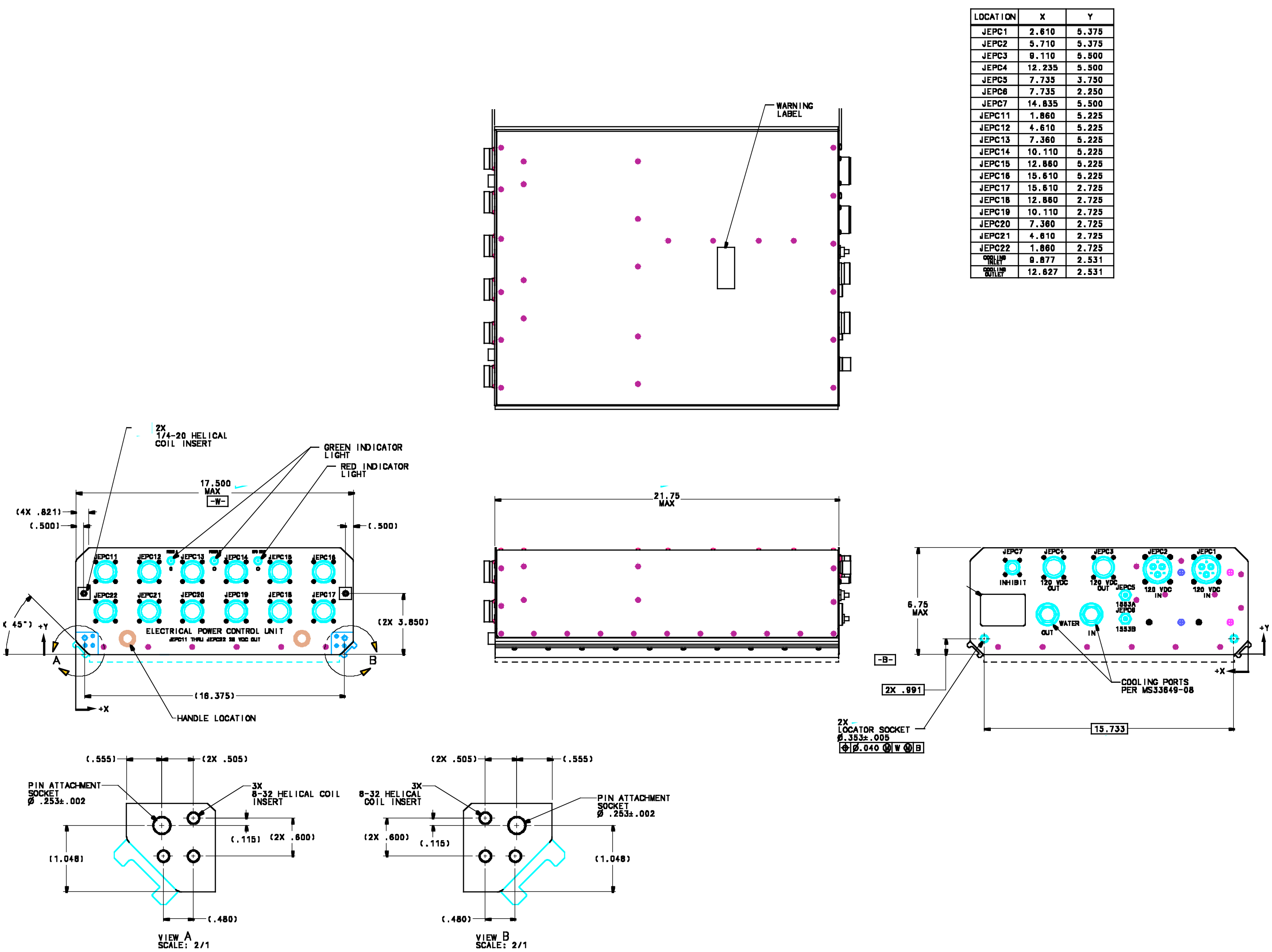
Figure 13 EPCU sketches

3.2.2.1 Mass

The total mass of the EPCU, not including handling fixture or cooling fluid, shall not exceed 55Kg (121.253 lbs).

3.2.2.2 Envelope

Package Envelope: The EPCUs shall be mounted in the bottom of a rack. The height of the EPCU shall not be greater than 6.75" high, 21.75" deep, and 17.5" wide, not including connectors, guide rails, screw heads, or handling fixture. Panel layout shall meet SSP 50005 Flight Crew Integration Standard requirements. The EPCU package envelope shall be designed to interface with the FCF guide rail. Package mounting envelope dimensions are defined in Figure 14.



LOCATION	X	Y
JEPC1	2.610	5.375
JEPC2	5.710	5.375
JEPC3	9.110	5.500
JEPC4	12.235	5.500
JEPC5	7.735	3.750
JEPC6	7.735	2.250
JEPC7	14.835	5.500
JEPC11	1.860	5.225
JEPC12	4.610	5.225
JEPC13	7.360	5.225
JEPC14	10.110	5.225
JEPC15	12.860	5.225
JEPC16	15.610	5.225
JEPC17	15.610	2.725
JEPC18	12.860	2.725
JEPC19	10.110	2.725
JEPC20	7.360	2.725
JEPC21	4.610	2.725
JEPC22	1.860	2.725
COOLING INLET	9.877	2.531
COOLING OUTLET	12.627	2.531

Figure 14. EPCU Envelope

3.2.2.3 Interface Characteristics

3.2.2.3.1 Electrical Interface

3.2.2.3.1.1 Connectors

The design of electrical connectors in the EPCU shall make it impossible to inadvertently reverse a connection or mate the wrong connectors so as to create a hazardous condition. The design of electrical connectors in the EPCU will ensure that no blind connections or disconnections are made during payload installation, operation, removal, or maintenance on orbit unless the design includes scoop proof connectors or other protective features. Although identification markings or labels are required, the use of identification alone is not sufficient to preclude incorrect mating.

A. Number of Connectors: Connectors shall be arranged as shown in Figure 15. Pin assignments shall be as shown in Table VII.

B. Powered Connectors: The powered side of the connector shall be terminated in sockets rather than pins.

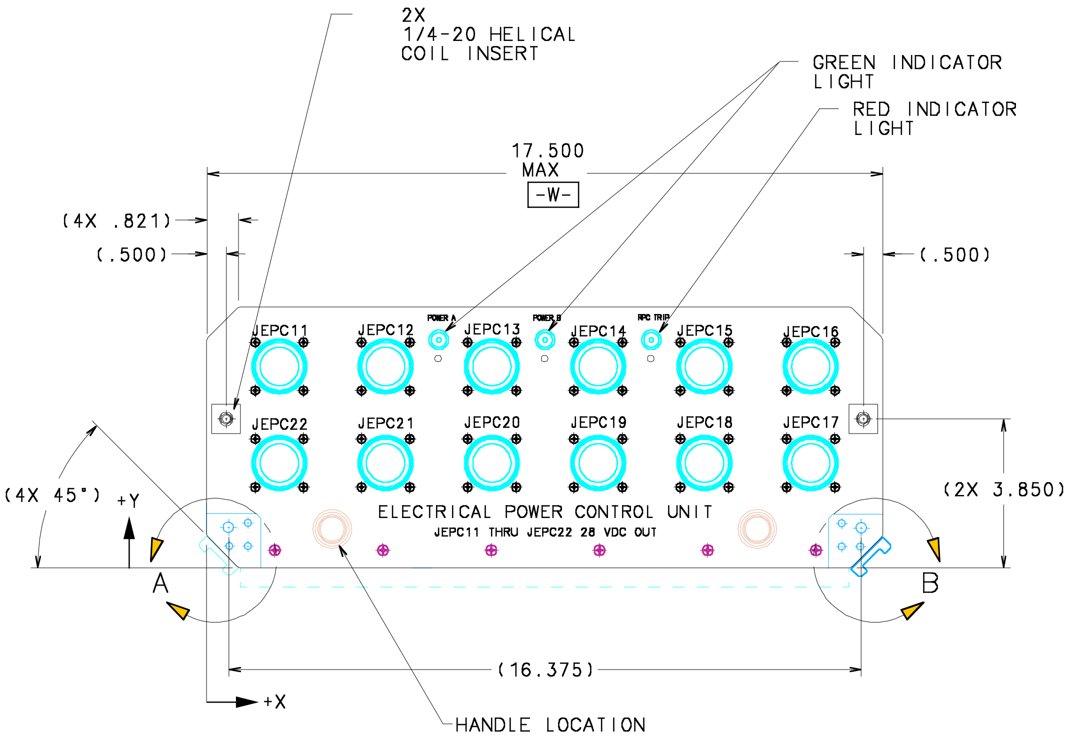
C. Connector Models: The required connector models for the EPCU are shown in Table VI.

D. Connectors and Tools Provided: Contractor shall furnish both halves of all EPCU connectors for each EPCU delivered to Glenn Research Center (GRC). Contractor shall also furnish one set of crimping tools necessary to fabricate any of the EPCU mating connectors onto their respective cables. (National Aeronautics and Space Administration (NASA) to define back shell requirements for mating half.) Note: If tools have been received from previous EM contract then only the connectors are required.

E. The EPCU shall be delivered with permanent (metal) un-tethered dust covers (part numbers as shown in Table VI) installed on all connectors to protect against physical damage and contamination. For J1 and J2 dust cover PN 660-005M28N shall be used. For J3, J4, J11-J22 dust cover 660-024M21N shall be used. For J5 and J6 dust cover RFI155-1 shall be used. For J7 dust cover 660-015M13N shall be used.

Designation	Description	EPCU Part Number	Mating Part Number	Mate Backshells	Notes
J1, J2	120 Vdc Input Power	MS3452L28-22P	MS3459L28-22S	380AS003M2812A3 (straight) 380AA003M2812A (rt. angle)	MS21981-187 Ferrules (adapter for #8 wire)
J3, J4	120 Vdc Output Power	D38999/20FG16SA	D38999/26FG16PA	380HS003M2116A3	
J5, J6	1553 Interface	BJ-154	Not Supplied	N/A	Subminiature Twinax 3-lug
J7	1553 Address and Control	D38999/20FC35SN	D38999/26FC35PN	380HS003M1306A3	
J11 - J22	28 Vdc Output Power	D38999/20FG16SN	D38999/26FG16PN	380HS003M2116A3	

Table VI. Connector Part Numbers



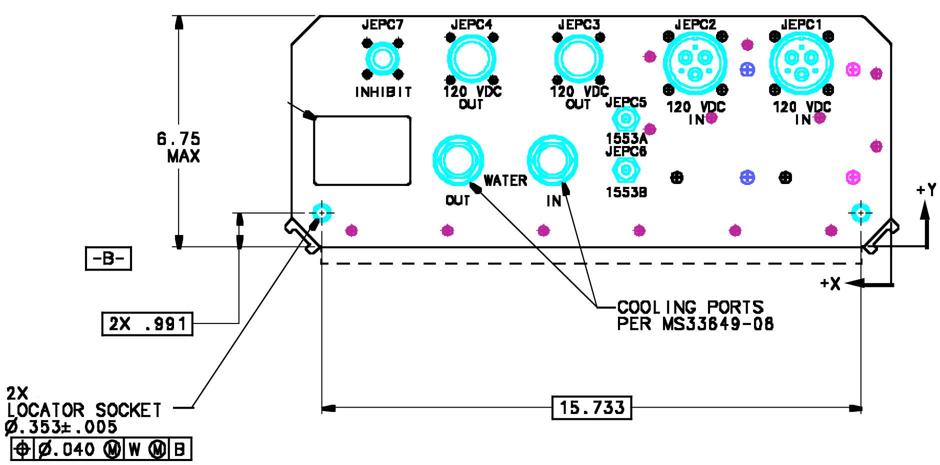


Figure 15. EPCU Connector Placement and Labeling Marking

Connector	Description
J1-A	Input 120V Bus A +
J1-B	Chassis
J1-C	Input 120V Bus A -
J2-A	Input 120V Bus B +
J2-B	Chassis
J2-C	Input 120V Bus B -
J3-J4 A	120V RPC 1 Power Out
J3-J4 B	120V RPC 1 Power Return
J3-J4 D	120V RPC 2 Power Out
J3-J4 E	120V RPC 2 Power Return
J3-J4 G	120V RPC 2 Power Out
J3-J4 H	120V RPC 2 Power Return
J3-J4 M	120V RPC 1 Parallel Pin
J3-J4 N	120V RPC 2 Parallel Pin
J3-J4 P	120V RPC 3 Parallel Pin
J3-J4 S	120V RPC Initial Position Pin
J3-J4 C	120V RPC Sense Pins Return
J5-INNER	1553 Bus A +
J5-OUTER	1553 Bus A -
J6-INNER	1553 Bus B +
J6-OUTER	1553 Bus B -
J7-1	External 28V Input
J7-2	Internal Bias 28V Sense
J7-5	RT Address 0
J7-6	RT Address 1
J7-7	RT Address 2
J7-8	RT Address 3
J7-9	RT Address 4
J7-10	RT Parity
J7-11	RT Address Return
J7-12	Control switch
J7-13	Control switch Return
J11-J22 A	28V RPC 1 Power Out
J11-J22 B	28V RPC 1 Power Return
J11-J22 D	28V RPC 2 Power Out
J11-J22 E	28V RPC 2 Power Return
J11-J22 G	28V RPC 3 Power Out
J11-J22 H	28V RPC 3 Power Return
J11-J22 K	28V RPC 4 Power Out
J11-J22 L	28V RPC 4 Power Return
J11-J22 M	28V RPC 1 Parallel Pin
J11-J22 N	28V RPC 2 Parallel Pin
J11-J22 P	28V RPC 3 Parallel Pin
J11-J22 R	28V RPC 4 Parallel Pin
J11-J22 S	28V RPC Initial Position Pin

Table VII. EPCU Connector Pin Assignments

3.2.2.3.2 Mechanical Interface

3.2.2.3.2.1 Mounting Interface

The EPCU shall be mounted in the rack using the following design per Figure 16.

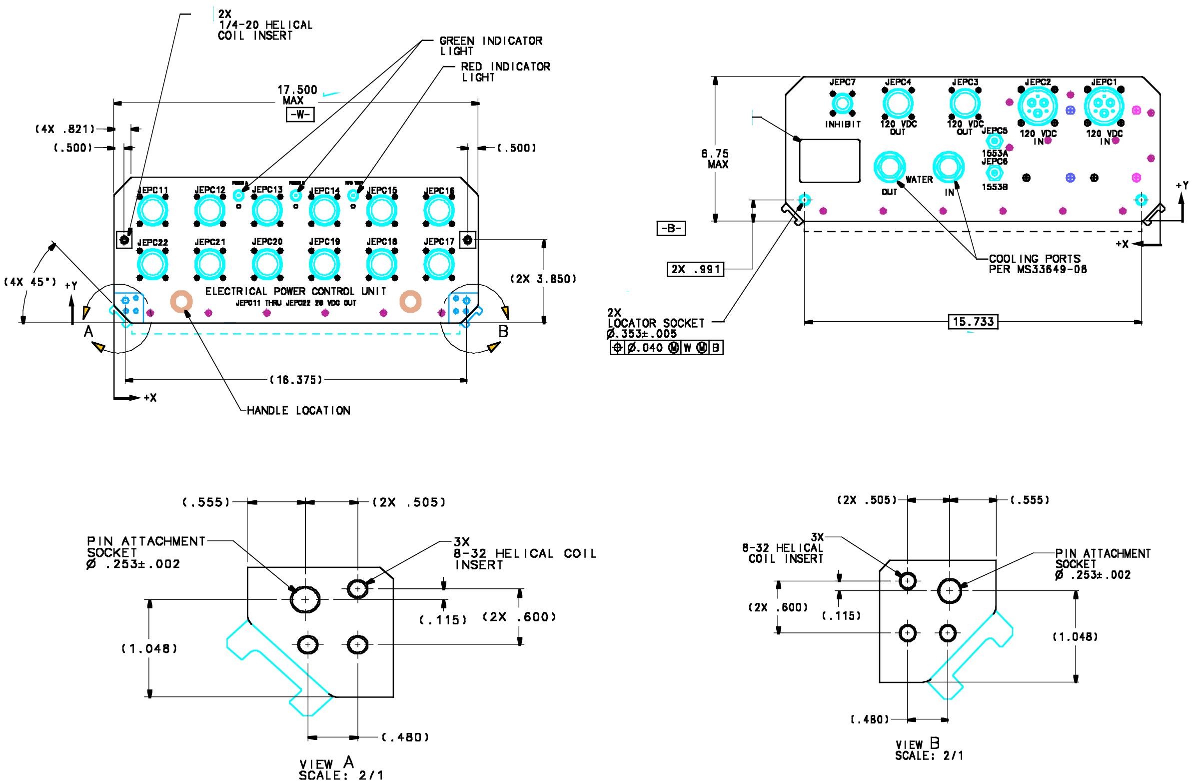


Figure 16. Attachment Detail

3.2.2.3.3 Thermal Interface

3.2.2.3.3.1 Thermal Management System

All EPCU thermal management, with the exception of the heat loss to the pressurized volume through radiation and convection (see section 3.2.2.3.3.9), shall be provided via a cold plate system (furnished by the Contractor) integral to the EPCU.

3.2.2.3.3.2 Coolant Outlet Temperature

The EPCU coolant outlet temperature shall not exceed 100 degrees F for all coolant inlet conditions specified below while delivering full rated output power of 5880 watts (3 kW @ 28 Vdc plus 2.88 kW @ 120 Vdc) under specified environmental conditions.

The EPCU shall be capable of nominal operation over the following output power levels, power dissipations, coolant flow rates and inlet temperatures:

28V load kW	120V load kW	Power Dissipation Watts	Flow rate Lbs/Hr	Inlet Temp Degrees F
1.5	0	186	125	95
3.0	0	370	200	94
3.0	2.88	404	330	96

Table VIII. EPCU Thermal Interface Characteristics

3.2.2.3.3.3 Heat Rejection to Thermal Control System (TCS)

Maximum watts to TCS shall be 404 watts when the EPCU is operating at 3 kW of 28 Vdc load and 2,880 W of 120 Vdc load (i.e. maximum EPCU load condition).

3.2.2.3.3.4 Cooling Fluid

Materials wetted to the TCS cooling fluid shall be compatible with the TCS cooling fluid. The TCS cooling fluid is identified as HEAT TRANSPORT FLUID (INTERNAL ACTIVE THERMAL CONTROL) in SSP 30573, Table 4.1-2.8. Materials compatibility is detailed in Note #11 of this table.

3.2.2.3.3.5 Pressure Drop

Maximum pressure drop between the coolant inlet and discharge threaded fittings shall be 1.25 psid at a flow rate of 350 LB/HR.

3.2.2.3.3.6 Coolant Maximum Operating Pressure

Maximum operating pressure shall be 130 psia.

3.2.2.3.3.7 Proof Pressure

Proof pressure shall be 260 psia.

3.2.2.3.3.8 Leakage Rate

The external leakage rate of the cold plate and fluid containing system shall not exceed 1 X 10^{-6} scc He/sec at one atmosphere differential pressure at an ambient pressure of one atmosphere. The leakage rate applies to the system including the quick disconnect (QD) O-ring interface to the EPCU. (O-ring part number AS-568-A908, fluorocarbon).

3.2.2.3.3.9 Heat Loss to Pressurized Volume

Under steady state conditions and with cooling water flow rates consistent with Table VIII, the average EPCU exterior surface temperature shall not exceed 15 degrees Fahrenheit above the average cooling water temperature (EPCU water inlet to water outlet).

3.2.2.3.3.10 Fluid Interface

Fluid connections shall be provided using a threaded boss per MS33649-08.

3.2.2.3.3.11 Touch Temperature

See paragraph 3.3.6.10.11.

3.2.2.3.3.12 Burst Pressure

Minimum burst pressure for the EPCU cold plate and associated plumbing shall be (2.5 X 130 psia) 325 psia.

3.2.2.3.3.13 Cooling System Cleanliness

See paragraph 3.3.4.1.2.

3.2.2.3.3.14 Fluids

After the fluid system has been cleaned, the only fluids permitted into the fluid system shall be per SSP 30573A table 4.1-1.9.2.

3.2.2.3.4 Data Interface

The EPCU data bus interface shall be MIL-STD-1553B long stub remote terminal (RT) capable of processing normal commands (EPCU controlled variables), status, and data at a nominal 1 second rate. Microprocessor and/or Software based control or data implementation shall not be utilized in the EPCU.

All internal temperature, voltage, and current sensor data is communicated to the FCF CDMS via a redundant 1553B interface bus. Two step commands for setting trip priorities, bus allocations, RPC state, etc. are accomplish through the CDMS via the 1553B interface.

3.2.2.3.4.1 EPCU Command Data Interface Characteristics

Definitions:

R-SA1   Receive command at sub-address one
R-SA2   Receive command at sub-address two
R-SA3   Receive command at sub-address three
R-SA3   Receive command at sub-address four
R-SA5   Receive command at sub-address five
R-SA6   Receive command at sub-address six

T-SA1   Transmit command at sub-address one
T-SA2   Transmit command at sub-address two
T-SA3   Transmit command at sub-address three
T-SA3   Transmit command at sub-address four
T-SA5   Transmit command at sub-address five
T-SA6   Transmit command at sub-address six

Load-Execute	R-SA1, R-SA2 sequence
Restart 1	R-SA5
Restart 2	R-SA6
Restart Sequence	R-SA5, R-SA6 sequence
Control Words	24 words located at SA1 and SA2
Discrete Words	32 words located at SA3
Analog Words	32 words located at SA4

AR bit: Alternate RAM bit
F: Tripflag bit
IOP: Input/Output Processor (station rack computer)
RAM: Random Access Memory
Peripheral assemblies: Assemblies inside the EPCU that communicate with the EPCU 1553 interface assembly (A11 PWA)

In the event of loss of communications via the MIL-STD-1553 interface, the EPCU shall continue to operate in the last commanded state.

A means to identify failures of sensors that are part of a control function shall be provided.

Functional Commands (Commands are bit patterns 1=ON, 0=OFF): Commands from external higher level controller

Although individual commands, status, and data words are specified herein, (table IX, X, and XI) the final implementation shall be a bit stream which is updated once per second which "codes" all incoming commands and "codes" outgoing status and data. All commands shall be two step commands, wherein the first command step permits the command to be loaded (arm) , and the second command step (fire) actually executes the command.

3.2.2.3.4.2 RESTART Command Sequence while in the idle state

The EPCU shall remain in an idle state following a power-up-reset (PUR) condition or a remote code 8 (reset RT mode code) command to facilitate RAM testing. The EPCU shall be removed from the idle state only when a “receive” command to Sub-address 5 (R-SA5) is followed by a “receive” command to Sub-address 6 (R-SA6). R-SA5 and R-SA6 data words shall not be used.

3.2.2.3.4.3 RESTART Command Sequence when Not in the idle state

The RESTART command sequence shall be used to reset the latched TRIPFLAG (word 29, bit 15 pf T-SA3) when the EPCU is not in the idle state. To reset the TRIPFLAG, the IOP must send a “receive” command to R-SA5 followed by a “receive” command to R-SA6. Data words shall not be used.

3.2.2.3.4.4 LOAD-EXECUTE Command Sequence and Data Validation

The EPCU configuration shall be controlled by the IOP via the EPCU 1553 interface using a two-step (LOAD EXECUTE) command sequence and a data validation process. To complete a LOAD-EXECUTE sequence, the IOP shall first send a “receive” command to Sub-address 1 (R-SA1) followed by 24 control words. These data words shall be stores sequentially in EPCU Random Access Memory (RAM) at predefined R-SA1 RAM addresses. Next, the IOP shall send a “receive” command and the same 24 words of data to Sub-address 2 (R-SA2). These data words shall be stored sequentially at predefined R-SA2 RAM addresses. When the 1553 interface logic is enabled (see restart command sequence), the data words at R-SA1 shall be compared (validated) to the respective data words at R-SA2. If “receive” commands to R-SA1 and R-SA2 were sent in the proper sequence and if data words in R-SA1 match the respective data words in R-SA2, then the validated control words shall be sent to peripheral assemblies in the EPCU.

Note 1: The data words in R-SA1 and R-SA2 shall be compared individually. Therefore, if one set of (R-SA1, R-SA2) data words don't match (invalid), this does not prevent other valid data words from being sent to the peripheral assemblies in the EPCU (so long as there is a LOAD-EXECUTE command sequence).

Note 2: It is not necessary for R-SA2 to immediately follow R-SA1 for a proper LOAD-EXECUTE sequence to occur. The sequence shall be interlaced with other commands so long as R-SA2 occurs after R-SA1. Additionally, multiple R-SA1 commands shall occur before the R-SA2 command and still maintain the proper command sequence.

Note 3: Prior to enabling the EPCU logic (leaving the idle state), command data to R-SA1 and R-SA2 shall be updated to ensure proper commanding of peripheral devices following a reset condition.

Note 4: While in the idle state, the EPCU shall communicate across the 1553 data bus. However, valid command data shall not be sent to EPCU peripheral assemblies until the EPCU control logic leaves the idle state (restarted).

3.2.2.3.4.5 Discrete Data

Thirty-two words of discrete data shall be acquired by sending a “Transmit” command to Sub-address 3 (T-SA3). all 32 discrete data words shall be refreshed every millisecond.

3.2.2.3.4.6 Analog Data

Thirty-two words of digitized analog data shall be acquired by sending a “Transmit” command to Sub-address 4 (T-SA4). Analog data words are 16 bits in length. However, only the least significant 12 bits represent actual data (see note below). One channel of analog data shall be refreshed every millisecond. Therefore, it takes 32 milliseconds to update the 32 channels.

Note: The upper four words of each 16 bit word contains the analog channel number. This bit structure was intended to correlate the 12 bit data to each analog channel for a 16-channel application. Since the upper four bits can decode only 16 channels, the feature is not applicable for this 32-channel application. The IOP shall extract only the 12 bit data.

Scaling: The analog data is unidirectional. Therefore, the range of values for each 12 bit word is 0 to 4095.

3.2.2.3.4.7 RAM Testing

RAM testing shall be accomplished following a Power-Up-Reset or Mode Code 8 (Reset RT) operation. The EPCU logic shall remain in the idle state so that it does not interfere with the RAM patterns sent from IOP. RAM patterns shall be sent in the following sequence or LOAD-EXECUTE sequence.

3.2.2.3.4.8 Sub-Address Sequence for RAM Testing

R-SA6, T-SA6, R-SA5, T-SA5, R-SA4, T-SA4, R-SA3, T-SA3, R-SA2, T-SA2, R-SA1, T-SA1

All Sub-addresses shall be fully tested with all desired test patterns before continuing with the next Sub-address pair in the sequence (R-SA6, T-SA6 is considered one pair).

Example: Send 000h test pattern to SA6 using R-SA6 command

Receive 0000h test pattern form SA6 using T-SA6 command
Send FFFFh test pattern to SA6 using R-SA6 command
Receive FFFFh test pattern to SA6 using T-SA6 command
Send AAAAh test pattern to SA6 using R-SA6 command
Receive AAAAh test pattern to SA6 using T-SA6 command
Send 5555h test pattern to SA6 using R-SA6 command
Receive 5555h test pattern to SA6 using T-SA6 command

Repeat the above sequence using other pairs (SA5 pair would be next).

3.2.2.3.4.9 Alternate RAM Block Selection

The EPCU shall have two alternate RAM locations for data storage. The RAM location for data storage shall be selectable by means of a 1553 interface command. The IOP shall select between two RAM blocks by sending a mode code 8 command to the EPCU. The EPCU shall reset the EPCU control logic to the idle state and the alternate RAM block shall be selected. If it is desirable to test the “last used” block of RAM, the IOP must transmit another mode code 8 command to return to the previous RAM block. An alternate RAM (AR) flag is located in status word 29, bit 14. The upper RAM block is active when the AR bit=1. Following a PUR, the EPCU shall alternate RAM selection defaults to the lower RAM block (AR bit=0).

3.2.2.3.4.10 Alternate Read Only Memory (ROM) Block Selection

In conjunction with alternate RAM function, the alternate ROM block shall be selected simultaneously.

3.2.2.3.4.11 Notification of EPCU RESET

The EPCU control logic shall remain in an idle state following a power-up reset condition or when a mode code 8 command (reset RT) is received from the IOP. The reset status shall be reported to the IOP using the subsystem flag located in the 1553 status word. The EPCU shall remain in the idle state and the subsystem flag shall remain active (bit 2=1) until the two step restart command sequence has been completed by the IOP. The 1553 status word shall be transmitted each time the IOP communicates with the EPCU. For prompt recognition of an EPCU reset condition, the IOP shall interrogate the subsystem flag each time it communicates with the EPCU.

1553 Data Format Summary

RT Address msb	T/R	Sub Address	Word Count	Description
- - - - -	0	00001	nnnnn	Receive nnnnn control words starting with word 1 (LOAD)
- - - - -	1	00001	nnnnn	Transmit nnnnn control word images starting with word 1
- - - - -	0	00010	nnnnn	Receive nnnnn acceptance words starting with word 1 (Accept all control word and acceptance word matches starting with word 1) (EXECUTE)
- - - - -	1	00010	nnnnn	Transmit nnnnn acceptance word images starting with word 1
- - - - -	0	00011	nnnnn	Receive nnnnn RAM test words starting with word 1
- - - - -	1	00011	nnnnn	Transmit nnnnn discrete status words (or RAM test words) starting with word 1
- - - - -	0	00100	nnnnn	Receive nnnnn RAM test words starting with word 1
- - - - -	1	00100	nnnnn	Transmit nnnnn analog status words (or RAM test words) starting with word 1
- - - - -	0	00101	nnnnn	Restart 1. The first of a two-step sequence to begin data acquisition and control functions following PUR or mode code 8 (RT reset). Removes logic from the idle state. ***Data words are not used.** When the logic is **not** in the idle state, the Restart 1 command is the first of a two-step sequence to clear the latched Tripflag indicator [F] (Bit 15 of status word 29).
- - - - -	0	00110	nnnnn	Restart 2. The second of a two-step sequence to begin data acquisition and control functions following PUR or mode code 8 (RT reset). Removes logic from the idle state. ***Data words are not used.** When the logic is not in the idle state, the Restart 2 command is the second of a two-step sequence to clear the latched Tripflag indicator [F] (Bit 15 of status word 29).

Table IX. Legal 1533 Data BUS Commands

*** Not necessary to complete RAM tests for SA6 and SA5 since the memory locations are not used.**

#	MSB															LSB	
1	-	-	-	-	-	-	-	-	8	7	6	5	4	3	2	1	Spare / 28V RPC Control
2	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1	Priority Load Set
3	8	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	Priority Load Set
4	-	-	-	-	-	-	-	-	16	15	14	13	12	11	10	9	Spare / 28V RPC Control
5	12	12	12	12	11	11	11	11	10	10	10	10	9	9	9	9	Priority Load Set
6	16	16	16	16	15	15	15	15	14	14	14	14	13	13	13	13	Priority Load Set
7	-	-	-	-	-	-	-	-	24	23	22	21	20	19	18	17	Spare / 28V RPC Control
8	20	20	20	20	19	19	19	19	18	18	18	18	17	17	17	17	Priority Load Set
9	24	24	24	24	23	23	23	23	22	22	22	22	21	21	21	21	Priority Load Set
10	-	-	-	-	-	-	-	-	32	31	30	29	28	27	26	25	Spare / 28V RPC Control
11	28	28	28	28	27	27	27	27	26	26	26	26	25	25	25	25	Priority Load Set
12	32	32	32	32	31	31	31	31	30	30	30	30	29	29	29	29	Priority Load Set
13	-	-	-	-	-	-	-	-	40	39	38	37	36	35	34	33	Spare / 28V RPC Control
14	36	36	36	36	35	35	35	35	34	34	34	34	33	33	33	33	Priority Load Set
15	40	40	40	40	39	39	39	39	38	38	38	38	37	37	37	37	Priority Load Set
16	-	-	-	-	-	-	-	-	48	47	46	45	44	43	42	41	Spare / 28V RPC Control
17	44	44	44	44	43	43	43	43	42	42	42	42	41	41	41	41	Priority Load Set
18	48	48	48	48	47	47	47	47	46	46	46	46	45	45	45	45	Priority Load Set
19	-	-	-	-	A	A	A	A	A	A	A	A	A	A	A	A	Bus A Allocation Set (FS = 64A)
20	R	S	T	U	B	B	B	B	B	B	B	B	B	B	B	B	Conv Control / UV Reset Enable
																	Bus B Allocation Set (FS = 64A)
21	-	-	-	-	-	-	-	-	-	6	5	4	-	3	2	1	Spare / 120V RPC Control
22	-	-	-	1	3	3	3	3	2	2	2	2	1	1	1	1	120V RPC Bus Set / Priority Load Set
23	-	-	-	2	6	6	6	6	5	5	5	5	4	4	4	4	120V RPC Bus Set / Priority Load Set
24	-	-	-	-	-	-	-	-	-	T	S	R	-	T	S	R	Conv Bus Set / Conv RPC Control

The number in each position indicates RPC channel # for data. For example, the "8" in the first row indicates the on/off control bit for RPC #8.

Bus Set: 0 = Bus A, 1 = Bus B
Control : 0 = off, 1 = on

Table X. Control Words (and Control Word Images)

#	MSB															LSB	
1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	28V RPC Trip / 28V RPC State
2	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1	Priority Load Echo
3	8	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	Priority Load Echo
4	P	7	6	5	P	3	2	1	8	7	6	5	4	3	2	1	28V Jumpers / Priority Trip
5	16	15	14	13	12	11	10	9	16	15	14	13	12	11	10	9	28V RPC Trip / 28V RPC State
6	12	12	12	12	11	11	11	11	10	10	10	10	9	9	9	9	Priority Load Echo
7	16	16	16	16	15	15	15	15	14	14	14	14	13	13	13	13	Priority Load Echo
8	P	15	14	13	P	11	10	9	16	15	14	13	12	11	10	9	28V Jumpers / Priority Trip
9	24	23	22	21	20	19	18	17	24	23	22	21	20	19	18	17	28V RPC Trip / 28V RPC State
10	20	20	20	20	19	19	19	19	18	18	18	18	17	17	17	17	Priority Load Echo
11	24	24	24	24	23	23	23	23	22	22	22	22	21	21	21	21	Priority Load Echo
12	P	23	22	21	P	19	18	17	24	23	22	21	20	19	18	17	28V Jumpers / Priority Trip
13	32	31	30	29	28	27	26	25	32	31	30	29	28	27	26	25	28V RPC Trip / 28V RPC State
14	28	28	28	28	27	27	27	27	26	26	26	26	25	25	25	25	Priority Load Echo
15	32	32	32	32	31	31	31	31	30	30	30	30	29	29	29	29	Priority Load Echo
16	P	31	30	29	P	27	26	25	32	31	30	29	28	27	26	25	28V Jumpers / Priority Trip
17	40	39	38	37	36	35	34	33	40	39	38	37	36	35	34	33	28V RPC Trip / 28V RPC State
18	36	36	36	36	35	35	35	35	34	34	34	34	33	33	33	33	Priority Echo
19	40	40	40	40	39	39	39	39	38	38	38	38	37	37	37	37	Priority Echo
20	P	39	38	37	P	35	34	33	40	39	38	37	36	35	34	33	28V Jumpers / Priority Trip
21	48	47	46	45	44	43	42	41	48	47	46	45	44	43	42	41	28V RPC Trip / 28V RPC State
22	44	44	44	44	43	43	43	43	42	42	42	42	41	41	41	41	Priority Echo
23	48	48	48	48	47	47	47	47	46	46	46	46	45	45	45	45	Priority Echo
24	P	47	46	45	P	43	42	41	48	47	46	45	44	43	42	41	28V Jumpers / Priority Trip
25	X	X	X	X	A	A	A	A	A	A	A	A	A	A	A	A	Bus A Allocation Echo (FS = 64A)
26	X	X	X	X	B	B	B	B	B	B	B	B	B	B	B	B	Bus B Allocation Echo (FS = 64A)
27	-	6	5	4	-	3	2	1	-	6	5	4	-	3	2	1	120V RPC Trip / 120V RPC State
28	-	-	-	1	3	3	3	3	2	2	2	2	1	1	1	1	Bus Selected / Priority Load Echo
29	F	AR	-	2	6	6	6	6	5	5	5	5	4	4	4	4	RPC Trip Flag/ Alternate RAM Bit/ Bus Selected / Priority Load Echo
30	P	-	5	4	P	-	2	1	-	6	5	4	-	3	2	1	120V Jumpers / Priority Trip
31	X	X	X	X	-	T	S	R	-	T	S	R	-	T	S	R	Conv RPC Trip / Conv Bus Selected / Conv RPC State
32	R	S	T	U	OC R	OC S	OC T	OV	UV	OV R	OV S	OV T	PS	OT R	OT S	OT T	Conv State / UV Reset Enable / Conv Discretes

The number in each position indicates RPC channel # for data. For example, the second "8" in the first row indicates the status bit for RPC #8.

"P" indicates initial position jumper installed.
"X" indicates non-data bits that are not guaranteed to be zero.

AR = Alternate RAM Selected
OC( ) = Overcurrent
OV = Input Overvoltage
UV = Output Undervoltage
OV( ) = Output Overvoltage
PS = Power Supply OK
OT( ) = Overtemperature

Table XI. Status Word Formats

3.2.3 Reliability

3.2.3.1 Failure Tolerance

The 120/28 Vdc internal control power supplies shall be dual redundant; that is, the control power supply shall be redundant even if one input bus is lost.

3.2.3.2 Mean Time Between Failure (MTBF)

The Mean Time Between Failure for the EPCU shall be greater than 30,000 hours for a mission length of 19,872 hours. (See Appendix C for the definition of MTBF and the specified reliability prediction analysis.)

3.2.3.3 Failure Propagation

The failure of the EPCU shall not cause the failure of any other payload element.(See appendix D for the specified failure modes and effects analysis to be performed to verify this requirement.)

3.2.4 Maintainability

3.2.4.1 Incorrect Equipment Installation

The EPCU shall contain physical provisions to preclude incorrect installation.

3.2.4.2 EPCU Mean Maintenance Crew Hours Per Year

N/A

3.2.4.3 EPCU Mean Time to Repair

N/A

3.2.5 Environmental Conditions

3.2.5.1 Deleted

3.2.5.2 Operating Temperature

The EPCU shall meet the performance requirements specified herein during exposure to air temperatures ranging from 17ºC to 30ºC.

3.2.5.3 Non-Operating Temperature

The EPCU shall meet the performance requirements specified herein after exposure to air temperatures ranging from 2ºC to 50ºC.

3.2.5.4 Operating Humidity

The EPCU shall meet the performance requirements specified herein during exposure to a dew point between 40 and 60 degrees F and relative humidity between 25 and 70 percent.

3.2.5.5 Non-Operating Humidity

The EPCU shall meet the performance requirements specified herein after exposure to humidity ranging from 10 to 90 percent relative humidity.

3.2.5.6 Pressure

The EPCU shall meet the performance requirements specified herein during exposure to ambient pressures ranging from 95.8 kPa to 104.8 kPa.

The EPCU shall meet the performance requirements specified herein after exposure to ambient pressures ranging from 0 kPa to 95.8 kPa.

3.2.5.7 Launch and Return

The EPCU shall be designed to withstand a minimum of two (2) shuttle launches and landings when exposed to environments defined herein.

3.2.5.8 Ionizing Radiation

The EPCU shall tolerate a total dose of 1kRads (Si) and a Linear Energy Transfer (LET) of 36 Mev-cm2/mg at a fluence of 1 x 10 ^6 particles per cm2.

3.2.5.8.1 Single Event (See) Ionizing Radiation

The EPCU shall meet specified performance and not produce an unsafe condition or one that could cause damage to equipment external to the integrated rack as a result of exposure to SEE ionizing radiation assuming exposure levels specified in SSP 30512, paragraph 3.2.1, with a shielding thickness of 25.4 mm (1000 mils).

3.2.5.9 Vibration

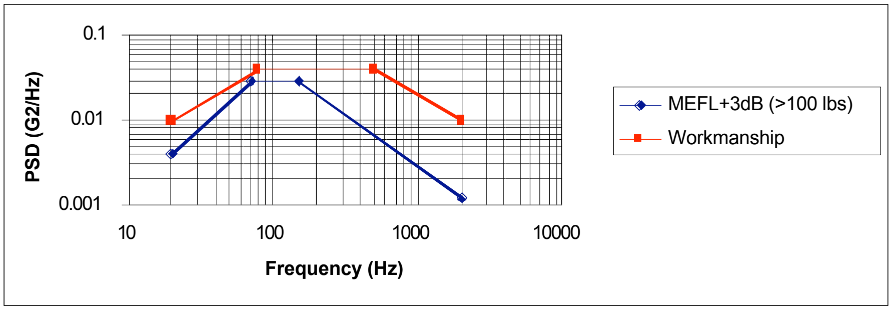
3.2.5.9.1 Loads and Vibration Environments

The EPCU shall be designed to withstand a minimum of two (2) shuttle launches and landings when exposed to environments defined herein. The EPCU is designed to withstand the liftoff and landing design loads defined in Table XII. (note that the X, Y and Z coordinates refers to the rack coordinate system defined in SSP 41017, Part 2, Paragraph 3.1.3). Tables XII taken from Figures XIIa and XIIb of SSP 57000, are included here for information purposes only.

The random vibration testing requirements for the EPCU are defined in Figures XIIA and XIIB. For qualification testing (Figure XIIa – 6.8 grms), the random vibration environment is defined as the envelope of the Maximum Expected Flight Environment (MEFLE) plus 3 dB and workmanship. The qualification test duration is 150 seconds per axis. For acceptance testing (Figure XIIb – 6.8 grms), the random vibration environment is defined as the envelope of the Maximum Expected Flight (MEFL) minus 3 dB and workmanship. The acceptance test duration is 60 seconds per axis. The EPCU shall have a minimum fundamental frequency of 35Hz for launch and landing.

Case	□ (g)	Y (g)	Z (g)
LIFTOFF			
1	±20.5	±11.6	±11.6
2	±7.7	±21.4	±11.6
3	±7.7	±11.6	±21.4
LANDING			
1	±5.4	±7.7	±8.8

Table XII. EPCU Design Load Factors

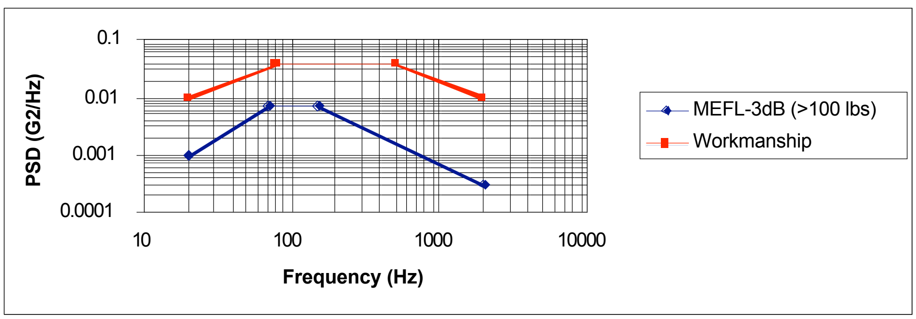


Qualification Envelope Test Specification

Figure XIIA. EPCU Qualification Random Vibration Environment

Test Duration (per axis):

Qualification:
150 seconds



Acceptance Envelope Test Specification

Figure XIIB. EPCU Acceptance Random Vibration Environment

Test Duration (per axis):

Acceptance
60 seconds

3.2.5.10 Acoustic

3.2.5.10.1 Ascent Acoustic Environments

Deleted. Ascent acoustic environments is accounted for by vibration environments.

3.2.5.10.2 Acoustic Emission Limits

The EPCU shall not emit acoustic energy to exceed the total Sound Pressure Level (SPL) of NC-38 in any octave band between 63 Hz and 8,000 Hz when measured at 2ft from any equipment surfaces.

3.2.5.11 Acceleration

3.2.5.11.1 On-Orbit Acceleration Environment

The EPCU shall meet specified performance in an on-orbit acceleration environment having peak transient accelerations of up to 0.4 g, acting in any direction, assuming a free boundary.

3.2.5.12 IVA Loads

The EPCU shall be able withstand loads generated by crew members during Intra Vehicular Activity (IVA) specifically "Cabinets or exposed equipment" provision as shown in Table XIII.

Legend: ft = feet, m = meter, N = Newton, lbf = pounds force

CREW SYSTEM OR STRUCTURE	TYPE OF LOAD	LOAD	DIRECTION OF LOAD
Personal Tether	Concentrated load (tension)	311.6 N (70 lbf), limit	Any direction
Personal Tether Attach Point	Concentrated load	1112.8 N (250 lbf), ultimate	Any direction
Handhold/Handrail Attach Points	Concentrated load at any point on the handhold/handrail	1112.8 N (250 lbf), ultimate	Any direction
Foot Restraints	Concentrated load at the plate surface	445.1 N (100 lbf), limit	Any direction
	Moment	203.3 N-M (150 ft-lbf), limit	Any direction
Levers, Handles, Operating Wheels, Controls	Push or Pull concentrated on most extreme edge	222.6 N (50 lbf), limit	Any direction
Small Knobs	Twist (torsion)	14.9 N-M (11 ft-lbf), limit	Either direction
Cabinets and any normally exposed equipment	Concentrated load applied by flat round surface with an area of (0.093 m^2) (1 ft^2)	556.4 N (125 lbf), limit 778.9 N (175 lbf), ultimate	Any direction

Table XIII. Crew Induced Loads

3.2.6 Transportability

3.2.6.1 Transportability Provisions

The EPCU shall be transportable within the United States, without damage, by truck, or air via common commercial carrier, when packaged as specified herein without requiring special accommodations (such as refrigeration, security escort, wide load, etc.).

3.2.6.2 Earth to Orbit Transportability

The earth to orbit transport of the Flight Segment shall be compatible with the standard transportation services provided by the Mini Pressurized Logistics Module (MPLM). The EPCU shall be designed to withstand the environment in the MPLM and withstand 2 launches and a landing.

3.2.6.3 Shipping, Handling, and Storage

Flight hardware shall be protected by the use of shipping containers designed according to NHB 6000.1 Requirements for Packaging, Handling, and Transportation of Aeronautical and Space Systems, Equipment, and Associated Components.

3.2.6.4 Transportation and Handling Accelerations

The EPCU shall meet the performance requirements specified herein after exposure, in its transportation and handling configurations, to the transportation and handling accelerations as specified in Table XIV.

Mode	Load Occurrence	Fore/Aft g's	Lateral g's	Vertical g's
Air	I	+/- 3.5	+/- 2.0	+ 3.5/0.0
Ground				
▪ Truck or air ride trailer	I	+/- 3.5	+/- 2.0	+ 3.5/-1.5
▪ Dolly (maximum velocity = 8 km/hr (5mph))	I	+/- 1.0	+/- 0.75	+2.0/0.0
▪ Forklifting	S	+/- 1.0	+/- 0.5	+2.0/0.0
Hoisting	I	1.5 in direction of travel		
Notes: (1) S – Loads occur simultaneously in the three directions. (2) I – Loads occur independently in the three directions except for gravity. (3) Above load factors act at center of gravity of cargo (rack, package, assembly, etc. (4) Cargo weighing <136 kgs. Subject to additional loads caused by vibroacoustics for applicable transportation modes. (5) For ground transportation, the structure/carrier vehicle should be designed for the occurrence of a 15.4 m/s wind in combination with the load factors. (6) Cargo support structure will be designed, or carrier operation constrained, or both to insure that cargo loads will not exceed the design load. (7) Limit load factors listed in this table may be superseded by limit load factors derived for specific combinations of transportation modes/vehicle, transportation handling fixtures and handling equipment. (8) Vertical g's are positive in the direction of gravity (downward).				

Table XIV. Transportation and Handling Limiting Load factors

3.3 Design and Construction

The EPCU shall have a design life that provides an on-orbit operating time of 19,872 hours. This includes the ability to endure the non-operating life cycle time, and be operational when called upon to perform EPCU functions. EPCU electronic hardware shall not drift, nor degrade, in functional output, or performance beyond specified limits over the planned on-orbit operating time specified herein.

3.3.1 Materials, Processes, and Parts

The GRC Office of Safety, Environmental and Mission Assurance shall determine the adequacy of the vendor's materials, processes and parts programs on a case by case basis.

3.3.1.1 Electrical, Electronic, and Electromechanical (EEE) Parts

Electronic, Electrical and Electromechanical (EEE) parts shall be selected and derated for the ISS FCF design in accordance with Goddard Space Flight Center's Preferred Parts List PPL-21, Grade 2. Any parts not available as Grade 2, shall be considered non-standard. All non-standard parts shall be selected, screened, and qualified in accordance with Goddard Space Flight Center Instructions 311-INST-001. A Non-Standard Part Approval Request (NSPAR) shall be generated, and submitted, including Specification Control Drawings as required, to the NASA Glenn Research Center for approval in accordance with paragraph 6.6 of 311-INST-001. A derating analysis shall be conducted on all EEE parts in the EPCU and shall be provided to the government as a deliverable before the EPCU design is base lined. This analysis report shall show that the actual operation levels, of all EEE parts used in the EPCU, are substantially less than the design maximum ratings. (Design maximum ratings usually relate to the maximum rating given to a part by its manufacturer. The closer a part is operated to its design maximum ratings, the greater the probability of failure.) The analysis shall be in the Contractor's standard format that provides the required technical content. Parts on the Space Station Approved Electrical, Electronic, and Electromechanical Parts List, SSP-30423 may be used without requiring a NSPAR; however, the governing requirements are specified herein.

3.3.1.1.1 EEE Parts Traceability

The contractor shall have a defined EEE Parts System. EEE parts quality and reliability requirements shall be determined and documented by the contractor to meet operational life requirements for EPCU. The Parts Identification List (PIL) shall be made available at Critical Design Review (CDR) by the contractor which contains the following information as a minimum.

- Subsystem Name
- Parts Designation
- Parts Description & Type
- Number of Parts used
- Part Number / generic part number
- Drawing Number

3.3.2 Electromagnetic Compatibility (EMC)

3.3.2.1.1 Electrical Grounding

The EPCU architecture shall employ a single point ground. Secondary electrical power shall be dc isolated from chassis, structure, equipment conditioned power return/reference, and signal circuits by a minimum of 1 megohm, individually, when all grounds are not terminated to chassis or structure.

3.3.2.1.1.1 Single Point Ground

Within the EPCU, conditioned electrical power shall be dc isolated from chassis and structure except at no more than one electrically conductive common point. Where termination is desired, the equipment designer has the option of either bringing the single point reference external to the equipment for termination to the nearest structure ground or, of terminating the reference point to the chassis internal to the equipment; both methods may be used simultaneously.

3.3.2.1.2 Electrical Bonding

The EPCU shall meet the requirements for Electrical bonding by providing a bonding area located on the front panel of the housing. This surface shall use a plated metallic finish. Selective or capsule plating of nickel is preferred, with adequate corrosion protection provided to counteract the dissimilar metal couple created. An area for this surface shall be capable of conducting maximum single fault current. The EPCU bonding area shall be 2 times this area. The bond shall result in a dc resistance of less than 2.5 milliohms across each faying surface in the bond path from enclosure to structure and an impedance of less than 100 milliohms up to a frequency of 1 megahertz.

3.3.2.1.3 Electromagnetic Interference (EMI)

The EPCU connected to Interface B shall meet all EMI requirements of SSP 30237 for conducted and radiated emissions and susceptibilities. The following tests shall be performed: CS01, CS02, CS06, RS02, RS03PL, CE01, CE03, CE07, and RE02. RS03PL is defined in paragraph 3.2.4.4 of SSP57000.

3.3.2.1.4 Electrostatic Discharge

When tested with the Human Body Model per MIL-HDBK-263B the unpowered EPCU and components shall not be damaged by Electrostatic Discharge (ESD) equal to or less than 4,000 V to the case or any pin on external connectors. EPCU that may be damaged by ESD between 4,000 and 15,000 V shall have a label affixed to the case in a location clearly visible in the installed position. Labeling of EPCU susceptible to ESD up to 15,000 V shall be in accordance with MIL–STD–1686A. These voltages are the result of charges that may be accumulated and discharged from ground personnel or crewmembers during equipment installation or removal.

3.3.2.1.5 Alternating Current (AC) Magnetic Fields

The generated ac magnetic fields, measured at a distance of 7 centimeters (cm) from the enclosure of the integrated rack, shall not exceed 140 dB above 1 picotesla for frequency at 30 Hz then falling 26.5dB per decade to 3.5kHz, and 85dB for frequencies ranging from 3.5kHz to 50 kHz.

3.3.2.1.6 Direct Current (DC) Magnetic Fields

The generated dc magnetic fields shall not exceed 170 dB picotesla at a distance of 7 cm from the enclosure of the integrated rack. This applies to electromagnetic and permanent magnetic devices.

3.3.2.1.7 EMI Susceptibility for Safety-Critical Circuits

N/A.

3.3.3 Nameplates and Product Marking

3.3.3.1.1 Product Marking for Ground Assembly and Handling

Product marking for ground assembly and handling shall be in accordance with MIL-STD-130.

3.3.3.1.2 Labeling

Label markings shall be standardized for format, location, and criteria in accordance with Figure 14.

3.3.3.1.3 Operating Instructions

N/A to EPCU.

3.3.3.1.4 Caution and Warning Labels

Caution and warning labels shall be in accordance with drawing 67211EFDE101.

3.3.4 Workmanships

The vendor shall work to a set of standards including but not limited to Military (Mil) specifications, commercial standards and any internal documentation defining manufacturing processes.

3.3.4.1.1 Cleanliness

Interior and exterior surfaces of flight articles shall conform to Visible Clean-Sensitive (VC-S) cleanliness requirements as specified in SN-C-0005, paragraphs "Cleanliness Level" and "Product Packaging"

3.3.4.1.2 Cleanliness of Surfaces in Contact With Fluids

Surfaces that are wetted by the TCS cooling fluid shall meet the minimum fluid system cleanliness levels specified in SN-C-0005C level 200A.

3.3.4.1.3 Internal Surfaces

See paragraph 3.3.4.1.2.

3.3.4.1.4 Packaging Designs

Packaging designs of items containing surfaces that will be in contact with fluids shall be in accordance with SN-C-0005, paragraph "Product Packaging," to maintain the cleanliness level until servicing with the working fluid.

3.3.4.1.5 Fungus Resistant Material

The EPCU shall use fungus resistant materials according to the requirements specified in SSP 30233, paragraph 4.2.10.

3.3.4.1.6 Burn In Testing

The EPCU shall be subject to burn-in testing with 100 hours at full load and maximum operating temperature. This test shall be used to operationally stress electronic and electrical components to precipitate early life failures.

3.3.5 Interchangeability

3.3.5.1.1 Intra-Rack Changeability

The EPCU will be able to integrate into either left or right side of rack.

3.3.5.1.2 Inter-Rack Interchangeability

The EPCU will be interchangeable between racks.

3.3.6 Safety

3.3.6.1. General

The EPCU shall meet all the Space Station payloads safety requirements listed in NSTS 1700.7B and NSTS 1700.7B Addendum These documents contain two types of requirements, programmatic and hardware. The hardware requirements (e.g. design, verification and handling) are clearly the responsibility of the contractor. Although the programmatic requirements (e.g. hazard reports and safety data packages) are the responsibility of GRC, the contractor is responsible for supporting this effort with the realization that the interpretation of the NSTS 1700.7B requirements is left to the authority of the Payload Safety Review Panel (PSRP). Therefore any design solution, which is implemented by the contractor, may be deemed unacceptable by the PSRP.

3.3.6.2 Payload Electrical Safety

The EPCU design shall protect the crewmembers from electrical hazards. In designing to minimize electrical shock hazards, controls shall be incorporated such that if the worst case credible failure can result in a crewmember exposed that:

Is below the threshold for shock (i.e., below maximum leakage current and voltage requirements as defined within this section), no controls shall be required.

Exceeds the threshold for shock and is below the threshold of let-go (critical hazard) as defined in Table XV, two independent controls (e.g., a safety (green) wire, bonding, insulation, leakage current levels below maximum requirements) shall be required such that no single failure, event, or environment can eliminate more that one control, or,

Exceeds the threshold of let-go (catastrophic hazardous events), three independent controls shall be required. If two dependent controls are provided, the physiological effect of the combinations of the highest internal voltage applied to or generated within the equipment and the frequency and wave form associated with a worst case credible failure that can be applied to the crewmember shall be below the threshold of let-go. Non-patient equipment with internal voltages not exceeding 30 volts rms (root-mean-squared) shall be considered as containing potentials below the threshold for electrical shock. If the classification of the hazard is marginal or unclear, three independent hazard controls shall be required. Note: The module can provide one verifiable upstream inhibit which removes voltage from the UIP and Utility Outlet Panel (UOP) connectors. The module design will provide the verification of the inhibit status at the time the inhibit is inserted. The use of the integrated rack power removal switch through J43 does not provide an additional inhibit.

FREQUENCY (Hz)	MAXIMUM TOTAL PEAK CURRENT (AC + DC COMPONENTS COMBINED) MILLIAMPERES
DC	40.0
15	8.5
2000	8.5
3000	13.5
4000	15.0
5000	16.5
6000	17.9
7000	19.4
8000	20.9
9000	22.5
>10000	24.3

Table XV. Let-Go Current Profile , Threshold vs. Frequency

3.3.6.3 Mating/Demating of Powered Connectors

The EPCU design for connectors shall meet the electrical safety requirements as defined in the following:

The specific approach is to eliminate potentially hazardous levels of energy from being present at the connector interface during mating/demating operations by limiting the energy of the power source or by isolating power sources from the connector. The design must prevent generation of molten metal, electrical shock, and damage to safety critical circuits.

The mating and demating of low power connectors (IVA) is permissible without any special design features. Low power connections are defined as those that limit short circuit power to 16 watts or less and with open circuit voltage no greater than 32 volts.
The design features described below are required for all connectors/circuits (IVA) that may require mating/demating and do not meet the low power criteria.

1. The powered side of the connector shall be terminated in sockets rather than pins.

2. Each powered circuit shall have at least one verifiable upstream inhibit which removes voltage from the connector. The design shall provide for verification of the inhibit status at the time the inhibit is inserted.

For IVA, when payloads have internal voltages greater than 32 volts, the following design features are also required:

IVA-1 The powered side (upstream) connector shall have a grounded back-shell.

IVA-2 When mating/demating recessed connectors (e.g., connectors attached to equipment that will be remote from the crew such as back-of-the-rack when the connectors are mated/demated, a design feature for grounding of the case shall be maintained while mating/demating the pin/sockets.

IVA-3 Payloads that are reconfigured such that their fault bond is disturbed during mate/demate operations, will require either redundant fault bonds to grounded structure or a post-installation test to verify a good fault bond has been established prior to payload power activation.

3.3.6.4 Bent Pin or Conductive Contamination

A. EPCU electrical design shall ensure that shorts between any pin within a connector that could be caused by a pin bent prior to or during connector mating cannot invalidate more than one inhibit to a hazardous function.

B. Conductive contamination as a similar cause shall be precluded.

3.3.6.5 Fire Protection

The EPCU design shall provide adequate air exchange for operation of the integrated rack smoke detector and fire suppression systems.

3.3.6.5.1 Fire Prevention

The EPCU shall be constructed out of materials selected for flammability and outgassing properties from the MAPTIS database to minimize the use of combustible materials.

3.3.6.6 Automatic Restarting Protection

Controls shall be employed that prevent automatic restarting after an overload-initiated shutdown.

3.3.6.7 Pressurized Volume Depressurization/Repressurization

The EPCU shall maintain positive margins of safety for unpowered depressurization rate of 890 Pa/second(7.75 psi/minute), and repressurization rate of 800 Pa/second(6.96 psi/minute).

3.3.6.8 Operation During Pressure Changes

The EPCU shall remain safe when exposed to pressures of 0 to 104.8 kPa.

3.3.6.9 Component Hazardous Energy Provision

Components, which retain hazardous energy potential, shall either be designed to prevent a crew member conducting maintenance from releasing the stored energy potential or shall be designed with provisions to allow safing of the potential energy including provisions to confirm that the safing was successful.

3.3.6.10 Human Engineering Safety

3.3.6.10.1 Internal Corner and Edge Protection

The EPCU shall protect crewmembers from exterior sharp edges and corners during all crew operations in accordance with the following:

A. The front and rear panel edges and cover edges shall be full radius.

B. The edges of thin sheets less than 0.02 inch(0.5 mm) thick shall be rolled or curled.

C. All other EPCU exterior edges and corners shall, at a minimum, maintain a 0.020 inch radius or 45 degree chamfer (0.020 x 0.020 inch).

Note that this requirement applies to holes, round or slotted, that are greater than 1.00 inch.

3.3.6.10.2 Latches

N/A to EPCU.

3.3.6.10.3 Screws and Bolts

N/A to EPCU.

3.3.6.10.4 Safety Critical Fasteners

Safety critical fasteners shall be designed to prevent inadvertent back out.

3.3.6.10.5 Levers, Cranks, Hooks and Controls

N/A to EPCU.

3.3.6.10.6 Handles

N/A to EPCU.

3.3.6.10.7 Securing Pins

N/A to EPCU.

3.3.6.10.8 Burrs

Exposed surfaces shall be free of burrs.

3.3.6.10.9 Holes

Holes that are round or slotted in the range of 10.0 to 25.0 mm (0.4 to 1.0 in.) shall be covered. Except for T handle holes in front of unit.

3.3.6.10.10 Locking Wires

N/A.

3.3.6.10.11 Touch Temperature

The EPCU shall be designed such that the average front surface temperature not to exceed 45° C (113° F).

3.3.6.10.12 Offgassing

The EPCU shall be within acceptable offgassing limits per NASA-STD-6001 Test number 7.

3.3.6.10.13 Safe Without Space Shuttle/ISS Program Services

The EPCU shall maintain fault tolerance or established safety margins consistent with the hazard potential without ground or flight Space Shuttle / ISS Program services.

3.3.6.10.14 Ignition of Adjacent Materials

Electrical equipment will not cause ignition of adjacent materials.

3.3.6.10.15 Accidental Contact With Electrical Equipment

Electrical equipment shall be designed to provide personnel protection from accidental contact with 50 volts direct current dc or any lower voltage that could cause injury.

3.3.6.10.16 Safety-Critical Circuits Redundancy

The EPCU shall be designed to include circuit protection devices to protect against circuit damage normally associated with an electrical fault when such a fault could result in damage to ISS or present a hazard to the crew by direct or propagated effects.

3.3.6.10.16.1 Safety-Critical Structure

The EPCU housing shall be considered a safety critical structure and comply with SSP52005 International Space Station Program Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures. Containment shall be provided in the housing design. Structure designated as hard points for mounting into the rack shall provide adequate margins of safety when exposed to the flight and launch loads.

3.3.6.10.17 Hazard Detection and Safing

The EPCU shall fail safe in the event of a total or partial loss of power or loss of cooling.

3.3.6.10.18 EPCU Output Over-Voltage and Under-Voltage Protection

EPCU output over-voltage and under-voltage protection shall be provided so as to protect the EPCU, and its downstream loads, and not to nuisance trip for the expected output voltage characteristics specified herein.

A). Switches/controls performing on/off power functions including 1553 commanding of EPCU connected to Interface B shall open (dead-face) all supply circuit conductors except the power return and the equipment grounding conductor while in the power-off position.

B). Power-off indications shall be used only if all parts, with the exception of overcurrent devices and associated EMI filters, are disconnected from the supply circuit.

C). Standby, charging, or other descriptive nomenclature shall be used to indicate that the supply circuit is not completely disconnected for this power condition.

Deadfacing shall be provided for each EPCU incoming power feed by the upstream RPCM. Deadfacing shall be arranged such that there is positive indication to the astronaut that the EPCU is in the safed position. When the EPCU is turned off, by means of the Rack Maintenance Switch Assembly (RMSA), the EPCU input leakage current for each ISS 120 Vdc power input shall be less than one milliampere.

3.3.6.10.19 Command and Computer Control of Hazardous Functions

Each integrated rack must provide a guarded, two-position, manual switch installed in a visible and accessible location on the front of the rack that removes all power to the integrated rack. The EPCU shall interface with this switch and provide the necessary means to remove power when required.

3.3.6.10.20 EPCU On/Off Inhibit Switch Interface

EPCU shall be designed to provide an On/off inhibit function interface in connector J7 as shown in Figure 12 EPCU Block diagram. Output of “control switch” and “control switch return”, listed in Table VII are connected to an EPCU shut-off switch. When this EPCU Shut-off switch is in OPEN position, the 28Vdc internal control power within the EPCU shall be removed from all EPCU circuits. All EPCU 120Vdc and 28Vdc channels shall be turned off and shall have no output voltage. The 120Vdc input from ISS is still present inside the EPCU if the Rack Power Switch has not been moved to the OFF position.

3.3.6.10.21 Hazardous Materials

Hazardous Materials shall not be released or ejected into the ISS habitable environment. During exposure to all ISS environments, hazardous fluids must be contained in the EPCU.

3.3.7 Human Performance/Human Engineering

3.3.7.1.1 Actuated Controls

The EPCU is controlled through 1553 bus commands. Deactivation for maintenance or emergency situations shall be accomplished via RMSA and or on/off inhibit switch.

3.3.7.1.2 Housekeeping

The EPCU shall be designed to facilitate housekeeping in accordance with the following:

A. Contamination Control During Ground Handling – Precautions SHALL be taken to prevent debris and surface contamination within Space Station and individual systems and components during ground operations from manufacture to launch.

B. Surface Materials – Materials used for exposed interior surfaces SHALL be selected to preclude particulate and microbial contamination and SHALL be smooth, solid, and non–porous.

C. Grids and Uneven Surfaces – Grids and uneven surfaces SHALL be removable and cleanable.

D. DELETED

E. Closures – Closures SHALL be provided for any area not designed for routine cleaning.

F. Fluid and Debris Collection/Containment – Means SHALL be provided for collecting and/or containing any loose fluids or debris.

G. Built–in Control – Subsystems which utilize containers of liquids or particulate matter SHALL have built–in equipment/methods for control of vaporization, material overflow, or spills.

(1) The capture elements including grids, screens, or filter surfaces SHALL be accessible for replacement or cleaning without dispersion of the trapped materials.

(2) Grid, screen, or filter surfaces SHALL be directly accessible for cleaning.

3.3.7.1.3 Temporary Storage Envelope

The EPCU requiring temporary storage during maintenance or replacement operation shall fit within a TBD storage volume.

3.3.8 Standards of Manufacture

The fabrication of the EPCU shall be performed in accordance with the vendor's standards, processes and specifications that have been approved by NASA.

3.4 Qualification (First Article)

The EPCU shall meet the requirements defined within this document and shall be validated and tested to ensure that requirements are met in accordance with test plans and procedures developed by the responsible organization per Statement Of Work (SOW) and or contract.

3.5 Standard Sample

Standard sample shall be defined as a flight level EPCU.

4.0 QUALITY ASSURANCE PROVISIONS

The following verification methods are specified in this section:

A. INSPECTION – Inspection is a physical measurement or visual evaluation of equipment and associated documentation. Inspection is used to verify construction features, drawing compliance, workmanship, and physical condition.

B. ANALYSIS – Analysis is the technical evaluation process of using techniques and tools such as mathematical models and computer simulation, historical/design/test data, and other quantitative assessments to calculate characteristics and verify specification compliance. Analysis is used to verify requirements compliance where established techniques are adequate to yield confidence or where testing is impractical.

C. DEMONSTRATION – Demonstration is the qualitative determination of compliance with requirements by observation during actual operation or simulation under preplanned conditions and guidelines.

D. TEST – Test is actual operation of equipment, normally instrumented, under simulated or flight equivalent conditions or the subjection of parts or equipment to specified environments to measure and record responses in a quantitative manner.

4.1 EPCU Definition

No Verification Required (NVR)

4.1.1 Interface Definition

NVR

4.1.1.1 Electrical

NVR

4.1.1.2 Mechanical

NVR

4.1.1.3 Thermal

NVR

4.1.1.4 Data BUS Interface

NVR

4.2 Characteristics

NVR

4.2.1 Performance Characteristics

NVR

4.2.1.1 Electrical Power Characteristics

Verification of electrical power characteristics shall be verified by subsequent requirement from section 3.2.1.2 through 3.2.1.26.

4.2.1.2 Steady State Voltage Characteristics

NVR

4.2.1.2.1 Interface B

Interface B Steady–state voltage requirements shall be verified by test.

Verification of operability and compatibility with Steady–state voltage limits shall be performed by test at high and low input voltage values of 116 to 126 Vdc.

The input power source shall represent ISS source impedance and shall be of fidelity of ISS on–orbit conditions. The EPCU and rack simulated loads shall be operated under selected loading conditions that envelope the operational loading.

The verification shall be considered successful when the test shows under high and low voltage conditions the EPCU can perform all functional capabilities and prove compatibility within the steady–state voltage limits of 116 to 126 Vdc.

4.2.1.3 Ripple Voltage Characteristics

4.2.1.3.1 Ripple Voltage and Noise

Ripple Voltage and Noise requirements shall be verified by test as prescribed in SSP 30237 CS01 and CS02.

Input power to the EPCU should be representative of the ISS power environment. The test procedures shall be in accordance SSP 30238 with the exception that source impedance for CS01 shall be equal to 2.0 ohms. The specified 100 microfarad DC power supply filter may be increased as required to provide a stable source for the test.

The verification shall be considered successful when the data from the CS01 and CS02 tests shows that the EPCU can perform all functional capabilities and prove compatibility with the EPS time domain ripple voltage and noise level of 5 Vrms maximum during high, nominal, and low voltage conditions from 30 Hz to 10 kHz.

4.2.1.3.2 Ripple Voltage Spectrum

Ripple Voltage and Noise requirements shall be verified by test as prescribed in SSP 30237 CS01 and CS02.

The verification shall be considered successful when the data from the CS01 and CS02 tests shows that the EPCU can perform all functional capabilities and prove compatibility with the ripple voltage spectrum in Figure 1 of this document.

4.2.1.4 Transient Voltages

Transient Voltages shall be verified by analysis and test. Input power to the integrated rack should be representative of the ISS power environment. Verification of operability and compatibility with the specified Transient Voltages shall be performed by test within the maximum and minimum Transient Voltage envelope as specified. ISS Transient Voltages shall be of fidelity of ISS on–orbit conditions.

The verification shall be considered successful when the test shows the integrated rack can perform all functional capabilities and prove compatibility within the EPS transient voltage characteristics as specified in section 3.2.1.4.

4.2.1.5 Fault Clearing and Protection

Fault Clearing and Protection shall be verified by test.

Verification of operability and compatibility with the specified Transient Voltages specified in section 3.2.1.5 shall be performed by test using voltage values as specified. For each input supporting functional capabilities of the EPCU, ISS Transient Voltages shall be of fidelity of ISS on–orbit conditions. The EPCU shall be safe and not suffer damage within the maximum and minimum Transient Voltage limits as specified.

The verification shall be considered successful when the test shows that the EPCU is safe and does not suffer damage within the EPS transient voltage limits as specified.

4.2.1.6 Non-Normal Voltage Range

Non–Normal Voltage Range shall be verified by test.

The power source connected to the EPCU shall be capable of producing 165 Vdc.
Verification of compatibility with Non–Normal voltage range conditions shall be performed by demonstration. The analysis shall ensure the EPCU will not produce an unsafe condition or one that could result in damage to ISS equipment external to the integrated rack when parameters are as specified for Interfaces B in section 3.2.1.3.4 of SSP 57000.

The verification will be considered successful when the test shows that the EPCU is safe within ISS interface conditions as defined in section 3.2.1.3.4.

4.2.1.7 Deleted

4.2.1.8 Power BUS Isolation

Power Bus Isolation requirements shall be verified by test and analysis.

Verification of Power Bus Isolation between two independent ISS Power Buses as specified, shall be performed by test. The Power Bus Isolation measurement applies to both the supply and return power lines. Verification of Power Bus Isolation without the use of diodes shall be verified by analysis. The analysis shall show the exclusion of diodes used to isolate the two independent ISS power bus high side or return lines.

The verification shall be considered successful when the test shows the EPCU provides a minimum of 1–megohm isolation in parallel with not more than 0.001 microfarad of mutual capacitance exists between the two independent power buses including both the supply and return lines. The verification shall be considered successful when the result of the analysis shows that the exclusion of diodes, to electrically tie together independent ISS power bus high side or return lines, exists.

4.2.1.9 Compatibility With Soft Start/Stop RPC

Compatibility with Soft Start/Stop RPC(s) shall be verified by test.

The verification shall be considered successful when test shows the EPCU can initialize operation and prove compatibility with the soft start/stop RPC characteristics, defined in section 3.2.1.9 represented in Figure 4.

4.2.1.10 Surge Current

Surge Current shall be verified by test and analysis.

Input power to the EPCU should be representative of the ISS power environment. Verification of compatibility with Surge Current limits shall be performed by test at high, nominal, and low input voltage values as specified. The power source used to perform the test shall be capable of providing 3 kW at 116–126 Vdc for Interface B. The analysis shall be performed using test data from the above test. The analysis shall indicate operability and compatibility exists based on test data and the requirements specified in section 3.2.1.10.

The verification shall be considered successful when test and analysis shows under high, nominal and low voltage conditions the EPCU can perform all functional capabilities and prove compatibility by operating within the specified limits of paragraph 3.2.1.10.

4.2.1.11 Reverse Energy/Current

Reverse Energy/Current shall be verified by test and analysis.

Input power to the EPCU should be representative of the ISS power environment. Verification of compatibility with Reverse Energy/Current limits shall be performed by analysis at 3 kW. The power source used to perform the analysis shall be capable of providing 3 kW at 116–126 Vdc for Interface B. The analysis shall be performed using test data from the above test.

The verification shall be considered successful when analysis shows that the EPCU complies with requirements defined in section 3.2.1.11 for the reverse energy/current into the upstream power source. Also, when the reverse energy or the reverse current requirement for all environmental conditions specified in this document when powered from a voltage source with characteristics specified in section 3.2.1.9 with a source impedance of 0.1 ohm is met.

4.2.1.12 Remote Power Controllers (RPCs)

Remote Power Controllers shall be verified by test and analysis.

A. Tests shall be performed to show the EPCU to Interface B operates and is compatible with the characteristics shown and described in Figure 7 section 3.2.1.12. The tests shall be performed at initiation of power to the EPCU. The verification shall be considered successful if the test results show the initial c current flow, when powered “on”, to the EPCU does not exceed the current magnitude and duration as defined and described in Figure7 section 3.2.1.12

B. Analysis of electrical circuit schematics shall be performed to show overcurrent protection exists where power is distributed to lower level (wire size not protected by upstream circuit protection device) available at the 28 Vdc and 120 Vdc connectors. The analysis shall be considered successful when results show overcurrent protection exists where power is distributed to lower level (wire size) at the 28 Vdc and 120 Vdc connectors.

C. Analysis of electrical circuit schematics shall be performed to show current limiting overcurrent protection exists for all internal loads drawing power from an interface B power feed(s). The analysis shall be considered successful when results show current limiting overcurrent protection exists in the distribution paths to all load devices connected to an interface B power feed(s).

4.2.1.13 RPC Trip Coordination

4.2.1.13.1 EPCU RPCs Trip Ratings

The EPCU Trip Ratings shall be verified by test and demonstration.

Input power to the EPCU should be representative of the ISS power environment. The test and demonstration shall be performed as specified in section 4.2.1.12.

The verification shall be considered successful when test and demonstration shows the requirements specified in paragraph 4.2.1.12 are met.

4.2.1.14 EPCU Input Impedances

4.2.1.14.1 Interface B

The following verification requirements apply to paragraph 3.2.1.14.1.

Integrated rack complex input impedance(s) shall be verified by test.

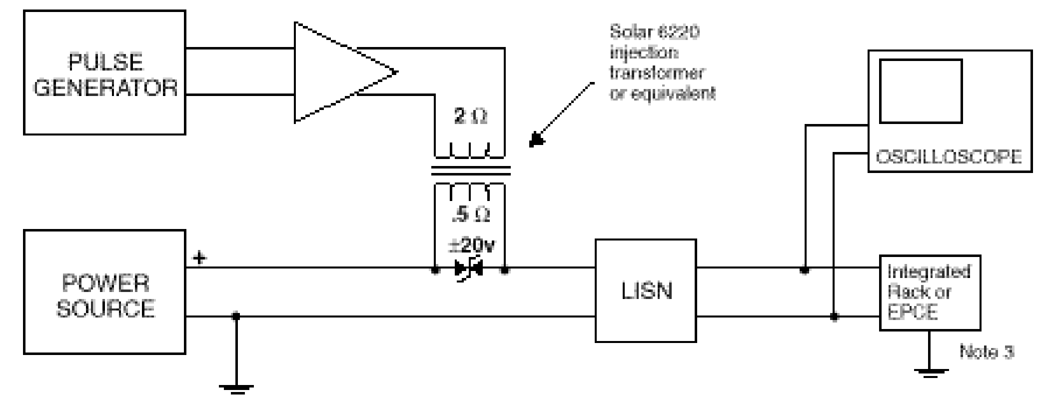
Loading of the EPCU can be simulated to provide full range of active converter loading. EPCU input impedance shall be tested under conditions of high, nominal, and low voltage to the EPCU. The simulated loads shall be exercised through the complete range of their loading. Selected combinations of loads that can influence the measured input impedance at Interface B shall be tested.

The verification shall be considered successful when the test shows that all input impedances measured for high, nominal and low voltage conditions remain within specified limits.

4.2.1.15 Large Signal Stability

Large signal stability shall be verified by test and analysis. A large signal stability test shall be conducted for the EPCU connected to simulated rack loads. A suitable power source shall simulate Interface B. An integrated analysis shall be provided for representative maximum and minimum case loads to demonstrate that impedance variations will not impact system stability. The input and transient response waveform for the EPCU shall be recorded from the start of the pulse through the time when the transient diminishes to and remains below 10 percent of the maximum amplitude of the response. The required test conditions may be produced using a programmable power source or the setup shown in Figure 20. The 25 amp and 50 amp LISN or equivalent is to be used for the EPCU and simulated rack loads. The pulse generator/amplifier must provide a source impedance of less than 0.2 ohms from 100 Hz to 10 kHz to the 2 ohm load of the primary side of the pulse transformer. Pulses of 100, 125 and 150 microsecond (±10 microsecond) duration shall be applied. The pulse amplitude at the secondary side of the injection transformer should be between 10 and 15 Volts. Pulse rise and fall times must not exceed 10 microseconds between 10 and 90 percent of the pulse amplitude. The resulting transient responses must remain within the EPS normal transient limits.

The test and analysis shall be considered successful when results show transient responses, measured at the input to the EPCU, diminish to 10 percent of the maximum amplitude within 1.0 millisecond and remain below 10 percent thereafter.



NOTES: 1. The output of the pulse generator must be applied to the transformer through a drive amplifier capable of providing an output impedance of 0.2 ohms, or less, from 100 Hz to 10 kHz.

2. The drive amplifier should be capable of delivering at least 75 watts rms into a 4 Ohm load and be suitable for EMC CS–01 tests.

3. Chassis of integrated rack must be grounded; portable equipment is not grounded.

4. Pulse generator, injection transformer and Zener diode may require adjustment to generate the test pulses and to protect the integrated rack or EPCE under test.

Figure 20. Stability Test Set Up, Transient Responses

4.2.1.16 Maximum Ripple Voltage Emissions

Maximum Ripple Voltage Emissions shall be verified by test.

Maximum Ripple Voltage induced on each of the power lines by the EPCU and simulated rack loads, shall be verified by test using the CE–07 test configuration of SSP 30238 (measured with a 20 MHz bandwidth instrument).

The verification shall be considered successful when test shows the EPCU and simulated loads does not induce voltage levels, at or upstream of the power source simulating Interface B, greater than 0.5 Volts peak-to-peak from supply to return line. Note: Measurement of transients, as defined in SSP 30237 CE–07, is not required in this test procedure.

4.2.1.17 Electrical Load-Stand Alone Stability

Local stability requirements shall be verified by analysis.

Verification shall be considered successful when analysis of test data for the requirements identified in the following paragraphs are met or waivers, deviations and requirement tailoring do not violate the local stability criteria.

- EMI test result from test (CS01)
- EMI test result from test (CS02)
- EMI test result from test (CS06)

4.2.1.18 EPCU Output Characteristics

4.2.1.18.1 Wire Derating

Wire derating shall be verified by analysis.

Analysis of the EPCU schematics shall be performed to show that the wire gauge of the EPCU meets the requirement of paragraph 3.2.1.18.1.

The verification shall be considered successful when the analysis shows the EPCU meets Wire Derating requirement as specified in paragraph 3.2.1.18.1.

4.2.1.18.2 Loss of Power

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU will fail safe in the event of loss of power defined in 3.2.1.18.2.

4.2.1.18.3 EPCU User Parameters

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the requirement in section 3.2.1.18.3 has been met.

4.2.1.18.4 Power Quality

4.2.1.18.4.1 Output Voltage Range

Voltage range shall be verified by test.

The verification shall be considered successful when the test data indicates that the requirement in section 3.2.1.18.4.1 has been met.

4.2.1.18.4.2 Ripple

Ripple shall be verified by test.

The verification shall be considered successful when the test data indicates that the requirement in section 3.2.1.18.4.2 has been met.

4.2.1.18.4.3 Transients

Transient levels shall be verified by test.

The verification shall be considered successful when the test data indicates that the requirement in section 3.2.1.18.4.3 has been met.

4.2.1.18.4.4 Current Limiting and Trip Function

The Current Limiting and trip function of the EPCU shall be verified by demonstration.

Verification shall be considered successful when the EPCU capabilities defined in section 3.2.1.18.4.4 have been demonstrated.

4.2.1.18.4.5 Parallel Operation

The Parallel operation function of the EPCU shall be verified by demonstration.

Verification shall be considered successful when the EPCU capabilities defined in section 3.2.1.18.4.5 have been demonstrated.

4.2.1.18.4.6 Remote Trip Function

The Remote trip function of the EPCU shall be verified by demonstration.

Verification shall be considered successful when the EPCU capabilities defined in section 3.2.1.18.4.6 have been demonstrated.

4.2.1.18.4.7 Initial Position

The initial position function shall be verified by demonstration.

Verification shall be considered successful when the EPCU channels configured for delivery of power at the moment power is applied to EPCU exhibit this capability. All channels shall be monitored to ensure power is not present on channels not configured for this function.

4.2.1.19 Health Monitoring Sensor Data

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the requirement in section 3.2.1.19 has been met.

4.2.1.20 EPCU Internal Sensors

Verification of EPCU internal sensors shall be verified by test.

The verification shall be considered successful when the test data indicates that the requirement in section 3.2.1.20. has been met.

4.2.1.21 Functional Performance

Functional performance of the EPCU shall be verified by test.

Verification shall be considered successful when the test data from functional testing indicates that the EPCU meets the requirements.

4.2.1.22 Load Shedding

The load shedding capability of the EPCU shall be verified by test.

Verification shall be considered successful when the test data from prioritized load shedding indicates that the requirement in section 3.2.1.22 has been met.

4.2.1.23 Failure Detection, Isolation and Recovery

The failure detection and isolation and recovery function of the EPCU shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the EPCU failure detection, isolation and recovery capability conforms to section 3.2.1.23.

4.2.1.24 Converter Characteristics

The characteristics of the converters in the EPCU shall be verified by test.

Verification shall be considered successful when the test data indicates that all of the parameters defined in section 3.2.1.24 have been met.

4.2.1.25 Solid State Current Limit Switch RPC Characteristics

The verification of the characteristics of the solid state current limit switches shall be by test.

Verification shall be considered successful when data from sections 4.2.1.18.4.5, 4.2.1.18.4.6 and 4.2.1.18.4.7 indicate that the solid state current limit switches meet the requirements defined in sections 3.2.1.18.4.5, 3.2.1.18.4.6 and 3.2.1.18.4.7.

4.2.1.26 Front Panel Indicators

The operation of the front panel indicators in the EPCU shall be verified by analysis.

The verification shall be considered successful when the analysis indicates the requirement defined in sections 3.2.1.26 has been met.

4.2.1.26.1 Power A

The verification of the input power bus A shall be by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.1.26.1 has been met.

4.2.1.26.2 Power B

The verification of the input power bus B shall be by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.1.26.2 has been met.

4.2.1.26.3 RPC Trip

The verification of the RPC trip shall be by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.1.26.3 has been met.

4.2.2 Physical Characteristics

4.2.2.1 Mass

The mass of the EPCU shall be verified by inspection.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.1 has been met.

4.2.2.2 Envelope

The envelope of the EPCU shall be verified by inspection.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.2 has been met.

4.2.2.3 Interface Characteristics

4.2.2.3.1 Electrical Interface

4.2.2.3.1.1 Connectors

The connectors of the EPCU shall be verified by inspection.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.1.1 has been met.

4.2.2.3.2 Mechanical Interface

The mechanical interface characteristics of the EPCU shall be verified by analysis and inspection.

The verification shall be considered successful when the analysis of the as built drawings for the EPCU as well as the Government Furnished Equipment (GFE) mounting rail and the inspection of the hardware are in agreement.

4.2.2.3.2.1 Mounting Interface

The mechanical interface characteristics of the EPCU shall be verified by analysis and inspection.

The verification shall be considered successful when the analysis of the as built drawings for the EPCU as well as the Government Furnished Equipment (GFE) mounting rail and the inspection of the hardware are in agreement.

4.2.2.3.3 Thermal Interface

NVR

4.2.2.3.3.1 Thermal Management System

Verification of thermal management via cold plate system shall be by inspection.

Verification shall be considered successful when the requirement in section 3.2.2.3.3.1 is met.

4.2.2.3.3.2 Coolant Outlet Temperature

The coolant outlet temperature of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.2 has been met.

4.2.2.3.3.3 Heat Rejection to Thermal Control System (TCS)

Verification of heat rejection to thermal control system shall be by test.

Verification shall be considered successful when the requirement in section 3.2.2.3.3.3 has been met.

4.2.2.3.3.4 Cooling Fluid

Verification of materials compatibility shall be by inspection. The inspection shall compare the materials and part list with the materials listed in SSP 30573, Table 4.1-2.8, Note #11.

Verification shall be considered successful when the inspection of the materials and parts list show the internal materials used in the cooling fluid system are compatible according to the table specified.

4.2.2.3.3.5 Pressure Drop

The pressure drop of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.5 has been met.

4.2.2.3.3.6 Coolant Maximum Operating Pressure

The coolant maximum operating pressure of the EPCU shall be verified by analysis.

Verification shall be considered successful when the analysis indicates that the requirement in section 3.2.2.3.3.6 has been met.

4.2.2.3.3.7 Proof Pressure

The proof pressure of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.7 has been met.

4.2.2.3.3.8 Leakage Rate

The leakage rate of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.8 has been met.

4.2.2.3.3.9 Heat Loss to Pressurized Volume

Verification of heat loss to the pressurized volume shall be by test. The test shall include each of the conditions shown in Table VIII-EPCU Thermal Interface Characteristics, paragraph 3.2.2.3.3.2. After reaching steady state conditions, surface temperatures shall be averaged to obtain a total average value. Top and bottom surfaces shall have 6 distributed measurements each, the remaining four sides shall have two distributed measurements each (total of 20 surface temperature measurements). During the test, the EPCU shall be physically supported in a manner to minimize conduction heat transfer to the supporting structure. Also during the test, the EPCU shall be shielded from forced air circulation.

Verification shall be considered successful when the test data indicates that the requirement in section 3.2.2.3.3.9 has been met.

4.2.2.3.3.10 Fluid Interface

The fluid interface characteristics of the EPCU shall be verified by inspection

4.2.2.3.3.11 Touch Temperature

The touch temperature of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.11 has been met.

4.2.2.3.3.12 Burst Pressure

The burst pressure of the EPCU shall be verified by test.

Verification shall be considered successful when the data indicates that the requirement in section 3.2.2.3.3.12 has been met.

4.2.2.3.3.13 Cooling System Cleanliness

The cooling system cleanliness of the EPCU shall be verified by inspection.

Verification shall be considered successful when the inspection shows that each part, component, subsystem and system of the end product meets the Visibly Clean-Sensitive (VC–S) requirement as specified in SN-C-0005 level 200A.

4.2.2.3.3.14 Fluids

Verification of the fluid shall be by inspection.

Verification shall be considered successful when the requirements in section 3.2.2.3.3.14 are met.

4.2.2.3.4 Data Interface

Verification of data interface shall be verified by subsequent requirements from section 3.2.2.3.4.1 through 3.2.2.3.4.11.

4.2.2.3.4.1 EPCU Command Data Interface Characteristics

The EPCU command data interface characteristics shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.1 are met.

4.2.2.3.4.2 RESTART Command Sequence while in the idle state

The RESTART command sequence while in the idle state shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.2 are met.

4.2.2.3.4.3 RESTART Command Sequence when Not in the idle state

The RESTART command sequence when not in the idle state shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.3 are met.

4.2.2.3.4.4 LOAD-EXECUTE Command Sequence and Data Validation

The LOAD-EXECUTE command sequence and data validation shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.4 are met.

4.2.2.3.4.5 Discrete Data

The discrete data shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.5 are met.

4.2.2.3.4.6 Analog Data

The analog data shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.6 are met.

4.2.2.3.4.7 RAM Testing

The RAM testing shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.7 are met.

4.2.2.3.4.8 Sub-Address Sequence for RAM Testing

The sub-address sequence for RAM testing shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.8 are met.

4.2.2.3.4.9 Alternate RAM Block Selection

The alternate RAM block selection shall be verified by test.

Verification shall be considered successful when the data from the test indicates that the requirements in section 3.2.2.3.4.9 are met.

4.2.2.3.4.10 Alternate Read Only Memory (ROM) Block Selection

The alternate ROM block selection shall be verified by inspection.

Verification shall be considered successful when the inspection indicates that the requirements in section 3.2.2.3.4.10 are met.

4.2.2.3.4.11 Notification of EPCU RESET

The notification of EPCU reset shall be verified by inspection.

Verification shall be considered successful when the inspection indicates that the requirements in section 3.2.2.3.4.11 are met.

4.2.3 Reliability

4.2.3.1 Failure Tolerance

The EPCU design shall contain sufficient failure tolerance to meet or exceed its reliability requirement. (See Appendix C, which contains the instructions for performing the reliability prediction analysis.) In addition, the failure tolerance of the design must meet the requirement in section 3.2.3.1.

4.2.3.2 Mean Time Between Failure (MTBF)

The MTBF shall be verified by analysis.

The verification shall be considered successful when the analysis estimate indicates that the EPCU MTBF is greater than 30000 hours.

4.2.3.3 Failure Propagation

A Failure Modes and Effects Analysis (FMEA) shall verify the failure of the propagation requirement.

The analysis shall be considered successful when the FMEA analysis shows that the EPCU will not cause the failure of any other ORU (Orbital Replacement Unit) in the event of any failure.

4.2.4 Maintainability

4.2.4.1 Incorrect Equipment Installation

An analysis of engineering design drawings shall be performed to verify features are provided which preclude incorrect installation of equipment.

The verification shall be considered successful when the analysis proves that physical provisions preclude incorrect installation (e.g. guides, location pins, orientation marks, etc.). See Appendix E.

4.2.4.2 EPCU Mean Maintenance Crew Hours Per Year

The verification of EPCU mean maintenance crew hours per year shall be at rack level.

4.2.4.3 EPCU Mean Time to Repair

N/A

4.2.5 Environmental Conditions

4.2.5.1 Deleted

4.2.5.2 Operating Temperature

Verification of operating temperature shall be by test.

The verification shall be considered successful when the test of data of the thermal test indicates that the operation of the EPCU meets the requirement in section 3.2.5.2.

4.2.5.3 Non-Operating Temperature

Verification of non-operating temperature shall be by test.

The verification shall be considered successful when the test data indicates that the operation of the EPCU meets the requirement in section 3.2.5.3.

4.2.5.4 Operating Humidity

Verification of operating humidity shall be by analysis.

The verification shall be considered successful when the analysis of operating humidity indicates that the operation of the EPCU meets the requirement in section 3.2.5.4.

4.2.5.5 Non-Operating Humidity

Verification of non-operating humidity shall be by analysis.

The verification shall be considered successful when the analysis indicates that the operation of the EPCU meets the requirement in section 3.2.5.5.

4.2.5.6 Pressure

Verification of pressure shall be by test.

The verification shall be considered successful when the test indicates that the EPCU meets the requirements in section 3.2.5.6. The test data shall be part of the hazard report.

4.2.5.7 Launch and Return

Verification of launch and return shall be by test.

The verification shall be considered successful when the test indicates that the EPCU meets the requirements in section 3.2.5.7.

4.2.5.8 Ionizing Radiation

Verification of ionizing radiation shall be by analysis and test.

The verification shall be considered successful when the analysis and test indicates that the EPCU meets the requirements in section 3.2.5.8.

4.2.5.8.1 Single Event Effect (SEE) Ionizing Radiation

Verification of single event effect ionizing radiation shall be by test and analysis.

The verification shall be considered successful when the test and analysis indicates that the EPCU when exposed to the environment defined in 3.2.5.8 shall not produce an unsafe condition or one that could cause damage to equipment external to the rack.

4.2.5.9 Vibration

4.2.5.9.1 Vibration Constraints

Verification of vibration shall be by test.

The verification shall be considered successful when the test results indicate that the EPCU will withstand the vibration levels in section 3.2.5.9.1

4.2.5.2.10 Acoustic

4.2.5.10.1 Ascent Acoustic Environments

NVR

4.2.5.10.2 Acoustic Emission Limits

Verification of acoustic limits shall be by test.

The verification shall be considered successful when test results indicate that the EPCU acoustic emissions are within levels defined in section 3.2.5.10.2.

4.2.5.11 Acceleration

4.2.5.11.1 On-Orbit Acceleration Environment

Verification of acceleration compatibility shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU can withstand acceleration levels defined in section 3.2.5.11.1

4.2.5.12 IVA Loads

Verification of IVA loads survivability shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU can withstand IVA loads in section 3.2.5.12.

4.2.6 Transportability

4.2.6.1 Transportability Provisions

Verification of transportation provisions shall be by analysis.

The analysis shall be considered successful when the data indicates that the EPCU meet the requirements in section 3.2.6.1.

4.2.6.2 Earth to Orbit Transportability

Verification of earth to orbit transportability shall be by analysis.

The analysis shall be considered successful when the data indicates that the EPCU meet the requirements in section 3.2.6.2.

4.2.6.3 Shipping, Handling, and Storage

Verification of shipping, handling, and storage shall be by analysis.

The analysis shall be considered successful when the data indicates that the EPCU meet the requirements in section 3.2.6.3.

4.2.6.4 Transportation and Handling Accelerations

Verification of transportation and handling accelerations shall be by analysis.

The analysis shall be considered successful when the data indicates that the EPCU is designed either to withstand these transportation accelerations, or is protected during handling and shipping by suitable equipment container design.

4.3 Design and Construction

Verification of design and construction shall be by analysis.

The analysis shall be considered successful when the data indicates that the EPCU meet the requirements in section 3.3.

4.3.1 Materials, Processes, and Parts

Verification shall be by inspection.

The verification shall be considered successful when inspection of vendor’s materials processes and parts programs meet the requirement in section 3.3.1.

4.3.1.1 Electrical, Electronic, and Electrochemical (EEE) Parts

Verification shall be by inspection

The verification shall be considered successful when documentation detailing the as built configuration of the EPCU indicates compliance with requirement in 3.3.1.1.

4.3.1.1.1 EEE Parts Traceability

Verification shall be by inspection.

The verification shall be considered successful when documentation detailing the as built configuration of the EPCU including the Parts Identification List (PIL), indicates compliance with requirement in 3.3.1.1.1.

4.3.2 Electromagnetic Compatibility (EMC)

4.3.2.1.1 Electrical Grounding

Verification shall be by analysis and test.

The verification shall be considered successful when the test data show that all power, signal and return lines are isolated from the chassis by a minimum of I megohm, individually, when all grounds are not terminated to chassis or structure.

4.3.2.1.1.1 Single Point Ground

Verification shall be by analysis and test.

The verification shall be considered successful when the analysis of the as built drawings and the resistance test indicate grounding criteria in section 3.3.2.1.1.1 has been met.

4.3.2.1.2 Electrical Bonding

Verification of bonding shall be by analysis.

The verification shall be successful when the analysis indicates that the bonding parameters in section 3.3.2.1.2 are met.

4.3.2.1.3 Electromagnetic Interference

Verification shall be by test.

The verification shall be considered successful when the test results indicate that the EPCU meets the requirements in section 3.3.2.1.3. Test shall be conducted per SSP30238, SSP30237 and SSP 30243.

4.3.2.1.4 Electrostatic Discharge

Verification shall be by test.

The verification shall be considered successful when test environment in accordance with section 3.3.2.1.4 and post test functional testing indicates compliance with these requirements.

4.3.2.1.5 Alternating Current (AC) Magnetic Fields

The AC Magnetic Fields requirement for the integrated rack connected to Interface B and EPCU shall be verified by test or analysis. The analysis should be based on the test data of the components which generate the magnetic fields. The test shall be performed using the MIL-STD-462D RE01 Method with the following modifications:

1. Test setup guidelines shall be per SSP 30238, Figure 3.2.3.1.4-1 or 3.2.3.1.4-2, not the setup identified by MIL-STD-462D.

2. Guidelines of SSP 30238, Figures 3.2.3.1.4-1 and 3.2.3.1.4-2, requirement of 1 meter separation does not apply to RE01.

3. Measurements are required from 30 Hz to 50 kHz rather than 100 kHz required by MIL-STD-461D.

4. Measurements are performed at 7 cm from the generating equipment. In the event emissions are out-of-specification, measurements are performed at 50 cm from the generating equipment.

5. Emissions greater than 20 dB below the specified limits shall be recorded in the EMI test report. In cases where the noise floor and ambient are not 20 dB below specified level, only those emissions above the noise floor/ambient are required to be recorded.

The verification shall be considered successful when test results show the generated ac magnetic fields of the integrated rack connected to Interface B, including cables and interconnecting wiring, do not exceed the magnetic fields emission limits of 140 dB above 1 picotesla for frequency at 30 Hz, and then falling 26.5 dB per decade to 3.5 kHz and 85 dB for frequencies ranging from 3.5 kHz to 50 kHz. Verification shall be by test. See section 4.3.2.4.6 of SSP 57000.

4.3.2.1.6 Direct Current (DC) Magnetic Fields

The DC magnetic fields requirement for the integrated rack connected to Interface B and EPCU with electromagnetic and/or permanent magnetic devices shall be verified by test or analysis. The measurement or analysis of DC magnetic fields shall be performed at 7 cm from the enclosure of the generating equipment. For integrated racks and EPCU that exceed the design requirement, measurements or analysis at 10 cm from the generating equipment shall be performed if there is a DC magnetic field greater than 170 dB above 1 picotesla. Additional measurements or analysis shall be performed at 10 cm increments away from the generating equipment until data proves the DC magnetic fields are 6 dB below the 170 dB above 1 picotesla requirement. The verification shall be considered successful when test or analysis results show the generated dc magnetic fields of the integrated rack connected to Interface B and EPCU do not exceed 170 dB above 1 picotesla at a distance of 7 cm from the generating equipment, including electromagnetic and permanent magnetic devices.

4.3.2.1.7 EMI Susceptibility for Safety-Critical Circuits

NVR

4.3.3 Nameplates and Product Marking

4.3.3.1.1 Product Marking for Ground Assembly and Handling

Verification shall be by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.3.1.1.

4.3.3.1.2 Labeling

Verification shall be by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.3.1.2.

4.3.3.1.3 Operating Instructions

NVR

4.3.3.1.4 Caution and Warning Labels

Verification shall be by inspection .

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.3.1.4.

4.3.4 Workmanship

Verification shall be by inspection.

The verification shall be considered successful when the inspection of drawing packages is in compliance with section 3.3.4.

4.3.4.1.1 Cleanliness

Verification shall be by inspection. An inspection of the cleanliness documentation required by precision cleaning shall be performed to show that the as built hardware meets the VC-S requirement.

The verification shall be considered successful when the inspection shows that the as built hardware meets the requirement in section 3.3.4.1.1.

4.3.4.1.2 Cleanliness of Surfaces in Contact With Fluids

Verification of the cooling system cleanliness shall be by inspection.

The verification shall be considered successful when the inspection shows that EPCU comply with the cleanliness level requirements as specified in SN-C-0005 level 200A.

4.3.4.1.3 Internal Surfaces

Verification shall be by inspection.

The verification shall be considered successful when the inspection of internal surfaces is in compliance with section 3.3.4.1.3.

4.3.4.1.4 Packaging Designs

Verification shall be by inspection.

The verification shall be successful when the inspection of the as built hardware is in compliance with section 3.3.4.1.4.

4.3.4.1.5 Fungus Resistant Materials

Verification of this requirement shall be by inspection. Inspection of design drawings and materials lists shall determine whether fungus resistant materials have been used as required.

The verification shall be considered successful when the inspection shows fungus resistant materials are used as required in section 3.3.4.1.5.

4.3.4.1.6 Burn-In Testing

Verification of this requirement shall be accomplished through review of the data pack which is shipped with each unit indicating that burn-in testing was successfully accomplished.

The verification shall be considered successful when the data from the test indicates that the EPCU electronic and electrical components did not experience any early life failures.

4.3.5 Interchangeability

4.3.5.1.1 Intra-Rack Interchangeability

NVR

4.3.5.1.2 Inter-Rack Interchangeability

NVR

4.3.6 Safety

4.3.6.1 General

Verification shall be by analysis, inspection and test.

The verification shall be considered successful when safety data compliance data packages are submitted and accepted by the PSRP.

4.3.6.2 Payload Electrical Safety

Verification of protection from electrical hazards shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.2.

4.3.6.3 Mating/Demating of Powered Connectors

Verification of protection from electrical hazards shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.3.

4.3.6.4 Bent Pin or Conductive Contamination

Verification of bent pins or conductive contamination shall be by inspection.

The verification shall be considered successful when inspection of connectors prior to mating indicate compliance with section 3.3.6.4.

4.3.6.5 Fire Protection

Verification of fire protection shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.5.

4.3.6.5.1 Fire Prevention

Verification of fire prevention shall be by analysis.

The Materials Identification Usage List (MIUL) shall be reviewed for flammable material usage as a part of the safety data package preparation. The verification shall be successful when the MIUL has been reviewed and data submitted.

4.3.6.6 Automatic Restarting Protection

Verification shall be by test.

The verification shall be considered successful when the data indicate that the EPCU meets the requirement in section 3.3.6.6.

4.3.6.7 Pressurized Volume Depressurization/Repressurization

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.7.

4.3.6.8 Operation During Pressure Changes

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.8.

4.3.6.9 Component Hazardous Energy Provision

Verification shall be by analysis.

The verification shall be considered successful when the analysis indicates that the EPCU meets the requirements in section 3.3.6.9.

4.3.6.10 Human Engineering Safety

4.3.6.10.1 Internal Corner and Edge Protection

Verification shall by inspection

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.6.10.1.

4.3.6.10.2 Latches

N/A

4.3.6.10.3 Screws and Bolts

N/A

4.3.6.10.4 Safety Critical Fasteners

An analysis shall be performed using data from drawings, integration documentation, and operational procedures to verify that safety critical fasteners will not back out under all environmental conditions.

Verification shall be considered successful when analysis indicates that the EPCU meets the requirements in section 3.3.6.10.4.

4.3.6.10.5 Levers, Cranks, Hooks and Controls

N/A

4.3.6.10.6 Handles

N/A

4.3.6.10.7 Securing Pins

N/A

4.3.6.10.8 Burrs

Verification shall by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.6.10.8.

4.3.6.10.9 Holes

Verification shall by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.5.10.9.

4.3.6.10.10 Locking Wires

N/A

4.3.6.10.11 Touch Temperature

This touch temperature of the EPCU shall be verified by test.

The verification shall be considered successful when the data indicates that the requirement in section 3.3.6.10.11 has been met for each of the conditions in Table VIII “EPCU THERMAL INTERFACE CHARACTERISTICS”.

4.3.6.10.12 Offgassing

Verification shall be by test.

The verification shall be considered successful when the test results indicates that the requirement in section 3.3.6.10.12 is met.

4.3.6.10.13 Safe Without Space Shuttle/ISS Program Services

Verification shall be by analysis.
The verification shall be considered successful when the analysis indicates that the EPCU shall maintain a safe condition if ISS cooling and or 1553 bus is interrupted.

4.3.6.10.14 Ignition of Adjacent materials

Verification shall be by test.

The verification shall be considered successful when the test results indicates that the requirement in section 3.3.6.10.14 is met.

4.3.6.10.15 Accidental Contact With Electrical Equipment

Verification of accidental contact with electrical equipment shall be verified by subsequent requirements in section 3.3.6.2 and 3.3.6.3.

4.3.6.10.16. Safety-Critical Circuits Redundancy

Verification shall be by analysis of as built drawings. Findings shall be submitted as part of hazard reports.

Verification shall be considered successful when hazard reports and safety data presented to the PSRP during the phased safety reviews are approved.

4.3.6.10.16.1 Safety-Critical Structures

Verification shall be by analysis of as built drawings. Verification shall be considered successful when the analysis indicates that the requirement in 3.3.6.10.16.1 is met.

4.3.6.10.17 Hazard Detection and Safing

Verification shall be by test. Total and partial loss of power shall be simulated as a part of the test.

The verification shall be considered successful when the results from the test results indicate that the EPCU meets the requirement in section 3.3.6.10.17.

4.3.6.10.18 EPCU Output Over-Voltage and Under-Voltage Protection

Verification shall be by test.

The verification shall be considered successful when the results from the test results indicate that the EPCU meets the requirement in section 3.3.6.10.18.

4.3.6.10.19 Command and Computer Control of Hazardous Functions

Verification shall be by test.

The verification shall be considered successful when the results from the test results indicate that the EPCU meets the requirement in section 3.3.6.10.19.

4.3.6.10.20 EPCU On/Off Inhibit Switch Interface

The verification of EPCU On/Off inhibit switch interface shall be at rack level.

4.3.6.10.21 Hazardous Materials

Verification shall be by test.

The verification shall be considered successful when the results from the test results indicate that the EPCU meets the requirement in section 3.3.6.10.21.

4.3.7 Human Performance/Human Engineering

4.3.7.1.1 Actuated Controls

Verification shall be by test.

The verification shall be considered successful when the results from the test results indicate that the EPCU meets the requirement in section 3.3.7.1.1.

4.3.7.1.2 Housekeeping

Verification shall by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.7.1.2.

4.3.7.1.3 Temporary Storage Envelope

NVR

4.3.8 Standards of Manufacture

Verification shall be by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.3.8.

4.4 Qualification (First Article)

Verification shall be by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.4.

4.5 Standard Sample

Verification shall be by inspection.

The verification shall be considered successful when the inspection of the as built hardware is in compliance with section 3.5.

5.0 PREPARATION FOR DELIVERY

The following requirements apply for all Flight Segment flight, flight-like, spare and qualification equipment and equivalent Ground Segment equipment in preparation for delivery to NASA. Delivery to NASA is to be considered as contractor to government or government to government, for the purposes of contractual acceptance or equivalent.

5.1 General

Connector dust covers shall be installed prior to shipping.

O-ring sealed plugs shall be installed prior to shipping. Ground handling fixture attached.

No fluid.

The package is sealed with desiccants.

5.2 Packaging, Handling and Transportation

Packaging, handling and transportation shall be in accordance with NHB 6000.1. The Flight Segment, spares and all other equipment shall be considered as Class I, for the purposes of applying NHB 6000.1. The accelerometer indicators shall be included in all packing/shipping configurations.

APPENDIX A – REQUIREMENT TRACEABILITY MATRIX

Note: This is reference information only and does not indicate specific requirements, only their origin.

PARAGRAPH	REQUIREMENT	DOCUMENT
3.2.1.1	Electrical power characteristics	SSP57000
3.2.1.2.1	Interface B	SSP57000
3.2.1.3.1	Ripple voltage and noise	SSP57000
3.2.1.3.2	Ripple voltage spectrum	SSP57000
3.2.1.4	Transient voltages Interface B	SSP57000
3.2.1.5	Fault clearing and protection	SSP57000
3.2.1.6	Non-Normal voltage range	SSP57000
3.2.1.7	Common mode noise	SSP30482
3.2.1.8	Power Bus Isolation	SSP57000
3.2.1.9	Compatibility with soft start/stop rpc	SSP57000
3.2.1.10	Surge Current	SSP57000
3.2.1.11	Reverse Energy Current	SSP57000
3.2.1.12	Remote Power Controllers (RPCs)	SSP57000
3.2.1.12	Remote Power Controllers (RPCs)	SSP57001
3.2.1.13.1	Payload trip ratings	SSP57000
3.2.1.14.1	EPCU Load Impedances Interface B	SSP57000
3.2.1.15	Large signal stability	SSP57000
3.2.1.16	Maximum ripple voltage emissions	SSP57000
3.2.1.17	Electrical load stand alone stability	SSP57000
3.2.1.18.1	Wire derating	SSP57000
3.2.1.18.2	Loss of Power	SSP57000
3.2.2.2	Envelope	SSP50005
3.2.2.3.1.1	Connectors	NSTS1700.7b
3.2.2.3.1.1	Connectors	SSP57000
3.2.2.3.3.2	Coolant Outlet Temperature	SSP57000
3.2.2.3.3.4	Cooling Fluid	SSP30573 RA
3.2.2.3.3.5	Pressure drop	SSP57000
3.2.2.3.3.6	Coolant Max Operating Pressure	SSP57000

PARAGRAPH	REQUIREMENT	DOCUMENT
3.2.2.3.3.8	Leakage	SSP57000
3.2.2.3.3.11	Touch Temperature	SSP57000
3.2.2.3.3.12	Burst Pressure	NSTS1700.7b
3.2.2.3.3.13	Cooling System Cleanliness	SSP30573 RA
3.2.2.3.3.14	Deionized Water	SSP30573 RA
3.2.2.3.4	Data Interface	MIL-STD-1553
3.2.5.2	Operating Temperature	SSP57000
3.2.5.3	Non-Operating Temperature	SSP57000
3.2.5.4	Operating Humidity	SSP57000
3.2.5.5	Non-Operating Humidity	SSP57000
3.2.5.6	Pressure	SSP57000
3.2.5.8	Ionizing Radiation Limits	SSP30512
3.2.5.9	Vibration Constraints	SSP57001
3.2.5.9	Vibration Constraints	SSP57217
3.2.5.10.2	Acoustic Emission Limits	SSP57217
3.2.5.11.1	On-Orbit Acceleration Environment	SSP41017
3.2.5.12	IVA Loads	SSP57000
3.2.6.3	Shipping, Handling and storage	NHB6000.1
3.2.6.3	Shipping, Handling and storage	LMI8070.2
3.2.6.4	Transportation and Handling Accelerations	FCF-SPEC-001
3.3.2.1.1	Electrical Grounding	SSP30240
3.3.2.1.2	Electrical Bonding	SSP57000
3.3.2.1.3	Electromagnetic Interference	SSP57000
3.3.2.1.4	Electrostatic Discharge	SSP57000
3.3.2.1.5	AC Magnetic Fields	SSP57000
3.3.2.1.6	DC Magnetic Fields	SSP57000
3.3.2.1.7	EMI Susceptibility for Safety Critical Circuits	SSP57000
3.3.3.1.2	Labeling	SSP57000
3.3.4.1.1	Cleanliness	SSP57000
3.3.6	Safety	NSTS1700.7b
3.3.6.3	Mating/Demating of Powered Connectors	SSP57000

PARAGRAPH	REQUIREMENT	DOCUMENT
3.3.6.6	Automatic Restarting Protection	SSP57000
3.3.6.7	Pressurized Volume Depressurization/Repress.	SSP57000
3.3.6.10.1	Internal Corner and Edge Protection	SSP57000
3.3.6.10.8	Burrs	SSP57000
3.3.6.10.9	Holes	SSP57000
3.3.6.10.11	Touch Temperature	SSP57000
3.3.6.10.12	Offgassing	NSTS1700.7b
3.3.6.10.13	Safe Without Space Shuttle Services	NSTS1700.7b
3.3.6.10.16	Safety-Critical Circuits Redundancy	SSP57000
3.3.6.10.17	Hazard Detection and Safing	NSTS1700.7b
3.3.6.10.19	Command and Computer Cont. of Haz Functions	NSTS1700.7b
3.3.6.10.20	Integrated Rack Power Removal Switch	SSP57000
3.3.6.10.21	Hazardous Materials	NSTS1700.7b
3.3.7.1.2	Housekeeping	SSP57000

APPENDIX B – EPCU TEST MATRIX

PARAGRAPH	REQUIREMENT	METHOD	TITLE
4.2.1.2.1	INTERFACE B	TEST	Power Converter Efficiency test
4.2.1.3.1	RIPPLE VOLTAGE AND NOISE	TEST	Ripple and noise test
4.2.1.4	TRANSIENT VOLTAGES	TEST OR ANALYSIS	
4.2.1.5	FAULT CLEARING AND PROTECTION	ANALYSIS	
4.2.1.6	NON-NORMAL VOLTAGE RANGE	ANALYSIS	
4.2.1.7	COMMON MODE NOISE	TEST	Common Mode Noise test
4.2.1.8	POWER BUS ISOLATION	ANALYSIS	
4.2.1.9	COMPATIBILITY WITH SOFT START/STOP RPC	TEST	Compatibility with rpc
4.2.1.10	SURGE CURRENT	ANALYSIS AND TEST	Compatibility with rpc
4.2.1.11	REVERSE ENERGY/CURRENT	ANALYSIS	
4.2.1.12	REMOTE POWER CONTROLLERS (RPCs)	ANALYSIS AND TEST	Compatibility with rpc
4.2.1.13.1	PAYLOAD TRIP RATINGS	TEST AND DEMONSTRATION	Compatibility with rpc
4.2.1.14.1	LOAD IMPEDANCE INTERFACE B	TEST	Impedance test
4.2.1.15	LARGE SIGNAL STABILITY	TEST AND ANALYSIS	Large signal stability test
4.2.1.16	MAXIMUM RIPPLE VOLTAGE EMISSIONS	TEST	EMI test
4.2.1.17	ELECTRICAL LOAD-STAND ALONE STABILITY	ANALYSIS	EMI test
4.2.1.18.1	WIRE DERATING	ANALYSIS	
4.2.1.18.3	POWER QUALITY	TEST	Functional test
4.2.1.18.4.1	VOLTAGE RANGE	TEST	Functional test
4.2.1.18.4.2	RIPPLE	TEST	Functional test
4.2.1.18.4.3	TRANSIENTS	TEST	Functional test
4.2.1.18.4.4	CURRENT LIMITING AND TRIP FUNCTION	DEMONSTRATION	Current limit demo
4.2.1.18.4.5	PARALLEL OPERATION	DEMONSTRATION	Current limit demo
4.2.1.18.4.6	REMOTE TRIP FUNCTION	DEMONSTRATION	Current limit demo
4.2.1.18.4.7	INITIAL POSITION	DEMONSTRATION	Current limit demo
4.2.1.20	EPCU INTERNAL SENSORS	TEST	Functional test
4.2.1.21	FUNCTIONAL PERFORMANCE	TEST	Functional test
4.2.1.22	LOAD SHEDDING	TEST	Functional test
4.2.1.23	FAILURE DETECTION, ISOLATION AND RECOVERY	TEST	
4.2.1.24	CONVERTER CHARACTERISTICS	TEST	Efficiency test
4.2.1.25	SOLID STATE CURRENT LIMIT SWITCH CHARACTERISTICS	TEST	Efficiency test
4.2.1.26	FRONT PANEL INDICATORS	TEST	Functional test
4.2.2.1	MASS	INSPECTION	
4.2.2.2	ENVELOPE	INSPECTION	
4.2.2.3.1	ELECTRICAL INTERFACE	ANALYSIS AND INSPECTION	

PARAGRAPH	REQUIREMENT	METHOD	TITLE
4.2.2.3.2	MECHANICAL INTERFACE	ANALYSIS AND INSPECTION	
4.2.2.3.3.2	COOLANT OUTLET TEMPERATURE	TEST	Coolant loop test
4.2.2.3.3.5	PRESSURE DROP	TEST	Coolant loop test
4.2.2.3.3.6	COOLANT MAXIMUM OPERATING PRESSURE	TEST	Coolant loop test
4.2.2.3.3.7	PROOF PRESSURE	TEST	Coolant loop test
4.2.2.3.3.8	LEAKAGE RATE	TEST	Coolant loop test
4.2.2.3.3.9	HEAT LOSS TO PRESSURIZED VOLUME	ANALYSIS	
4.2.2.3.3.11	TOUCH TEMPERATURE	TEST	
4.2.2.3.3.12	BURST PRESSURE	TEST	Coolant loop test
4.2.2.3.3.13	COOLING SYSTEM CLEANLINESS	INSPECTION	
4.2.2.3.4.1	EPCU COMMAND DATA INTERFACE CHARACTERISTICS	TEST	
4.2.3.2	MTBF	ANALYSIS	
4.2.3.3	FAILURE PROPAGATION	ANALYSIS	
4.2.4.1	INCORRECT EQUIPMENT INSTALLATION	ANALYSIS	
4.2.4.4	EPCU MEAN TIME TO REPLACE	ANALYSIS	
4.2.5.2	OPERATING TEMPERATURE	ANALYSIS	
4.2.5.6	PRESSURE	ANALYSIS	
4.2.5.8	VIBRATION CONSTRAINTS	TEST	Vibration test
4.2.5.10.2	ACOUSTIC EMISSION LIMITS	TEST	Acoustic test
4.2.5.11.1	ON-ORBIT ACCELERATION ENVIRONMENT	ANALYSIS	
4.2.5.12	IVA LOADS	ANALYSIS	
4.2.6.4	TRANSPORTATION AND HANDLING ACCELERATIONS	INSPECTION	
4.3.1	MATERIALS PROCESSES AND PARTS	INSPECTION	
4.3.1.1.1.1	SINGLE POINT GROUND	ANALYSIS AND TEST	
4.3.2.1.2	ELECTRICAL BONDING	ANALYSIS	
4.3.2.1.3	ELECTROMAGNETIC INTERFERENCE	TEST	EMI test
4.3.2.1.4	ELECTROSTATIC DISCHARGE	TEST	
4.3.2.1.5	ALTERNATING CURRENT (AC) MAGNETIC FIELDS	TEST	EMI test
4.3.2.1.6	DIRECT CURRENT (DC) MAGNETIC FIELDS	TEST	EMI test
4.3.2.1.7	EMI SUSCEPTIBILITY FOR SAFETY-CRITICAL CIRCUITS	TEST	EMI test
4.3.3.1.2	LABELING	INSPECTION	
4.3.3.1.4	CAUTION AND WARNING LABELS	INSPECTION	
4.3.4.1.1	CLEANLINESS	INSPECTION	
4.3.4.1.3	INTERNAL SURFACES	INSPECTION	
4.3.4.1	SAFETY GENERAL	ANALYSIS, INSPEC. &TEST	
4.3.6.2	PAYLOAD ELECTRICAL SAFETY	ANALYSIS	
4.3.6.3	MATING/DEMATING OF POWERED	ANALYSIS	

PARAGRAPH	REQUIREMENT	METHOD	TITLE
	CONNECTORS		
4.3.6.4	BENT PIN OR CONDUCTIVE CONTAMINATION	INSPECTION	
4.3.6.5	FIRE PROTECTION	ANALYSIS	
4.3.6.6	AUTOMATIC RESTARTING PROTECTION	TEST	
4.3.6.7	PRESSURIZED VOLUME DEPRESSURIZATION / REPRESSURIZATION	ANALYSIS	
4.3.6.8	OPERATION DURING PRESSURE CHANGES	ANALYSIS	
4.3.6.9	COMPONENT HAZARDOUS ENERGY PROVISION	ANALYSIS	
4.3.6.10.1	INTERNAL CORNER AND EDGE PROTECTION	INSPECTION	
4.3.6.10.4	SAFETY CRITICAL FASTENERS	ANALYSIS	
4.3.6.10.8	BURRS	INSPECTION	
4.3.6.10.9	HOLES	INSPECTION	
4.3.6.10.11	TOUCH TEMPERATURE	VERIFICATION	
4.3.6.10.12	OFFGASSING	ANALYSIS	
4.3.6.10.13	SAFE WITHOUT SPACE SHUTTLE PROGRAM SERVICES	ANALYSIS	
4.3.6.10.16	SAFETY-CRITICAL CIRCUITS REDUNDANCY	ANALYSIS	
4.3.6.10.17	HAZARD DETECTION AND SAFING	TEST	
4.3.6.10.18	EPCU OUTPUT OVER-VOLTAGE AND UNDER-VOLTAGE PROTECTION	TEST	
4.3.6.10.19	COMMAND AND COMPUTER CONTROL OF HAZARDOUS FUNCTIONS	TEST	
4.3.7.1.1	ACTUATED CONTROLS	TEST	
4.3.7.1.2	HOUSEKEEPING	INSPECTION	
4.3.8	STANDARDS OF MANUFACTURE	INSPECTION	
4.	QUALIFICATION (FIRST ARTICLE)	INSPECTION	
4.5	STANDARD SAMPLE	INSPECTION	

APPENDIX C – RELIABILITY ANALYSIS

C.1 Reliability Analysis

The requirement to perform a reliability prediction analysis of the EPCU results from a flow-down of requirements from SSP 50431. (Space Station Requirements for Payloads) The contractor shall develop a reliability block diagram, which represents successful operation of the EPCU designed for the Fluid-Combustion Facility Project. The analysis shall estimate EPCU reliability following 19,872 hours of operating time based upon the space-flight on-orbit environment intended for the EPCU. It will be assumed that the EPCU shall operate with a 330 lbs/hr flow rate, 96 degrees F inlet temperature, and a 100% duty cycle, and provides a 3.0 kW 28V power and 2.88kW 120V power output.

The reliability block diagram (RBD) shall include the internal redundancy of the EPCU. The EPCU shall be considered to operate successfully when it performs its intended functions in accordance with design specifications and in the environment specified herein. Successful operation of the EPCU shall be defined as operating with at least two of three converters, 44 of 48 28V FRPCs, one of four power supplies, and one of two 28V DC current sensors. The RBD should include major components such as Flexible Remote Power Controller Modules (FRPCMs), load converter module, 1553 interface, indicators, main switch, etc.

The reliability of the EPCU at 19,872 hours shall be estimated by using stress prediction method of MIL-HDBK-217F, Notice 2, or other applicable supporting data taken from tests or field performance. The EPCU shall be designed to have a MTBF (mean-time-between-failures) –greater than 30,000 hours. The MTBF shall be demonstrated by analysis. The MTBF shall be defined as the definite integral of the system reliability function R(t) from the start of the operating time (t=0) to the expected total operating time T , where - T=19,872 hours.

(1) $$MTBF = \int_0^T R(t)dt$$

The formula for R(t) shall be obtained from application of standard reliability modeling rules to the EPCU RBD, (Ref. MIL HDBK-338B, Electronic Reliability Design Handbook, or other sources on Reliability modeling techniques). For Parallel configurations (a group of like-components in active redundancy) the reliability may be estimated using:

(2) $$R_p(t) = \sum_{x=m}^{n} \frac{n!}{x!(n-x)!} \left\{R_i(t)\right\}^x \left\{1 - R_i(t)\right\}^{n-x}$$

where : n = The number of possible “paths” or “strings of devices” that can provide functional outputm = The number of operating “paths” or “strings” required for successful operation

Ri (t) = The reliability at elapsed operating time t, of individual channels

Rp (t) = The reliability at elapsed operating time t, of the parallel configuration

(3) $$R_p(t) = e^{-\lambda_{eq} t}$$

where λeq is the “equivalent failure rate”. The equivalent failure rate , λeq , for a redundant configuration can be calculated by first evaluating Rp(t) from (2) above, using T = 19,872 hrs. With Rp (T) the “equivalent failure rate” can be calculated for a redundant configuration in the RBD using the relation:

$$\lambda_{eq} = \frac{-\ln\left\{R_p(T)\right\}}{T}$$

where T= 19,872 hrs.

The contractor is permitted to use an alternative method for the evaluation of the MTBF for the EPCU, if so desired. (An alternate approach should be discussed with NASA GRC. (e.g. The Reliability Function R(t) can be derived for the EPCU and the integral in (1) may be computed by a computer program). Necessary deviations from the above “baseline” methodology can be negotiated as the reliability task proceeds.

The analysis results shall be provided in a deliverable “EPCU Reliability Prediction Analysis” report. A preliminary report shall be provided to NASA GRC -30 days after Preliminary Design Review (PDR). The final report is due at task order CDR. The Contractor Reliability Analysis Task is not complete until NASA GRC has approved the deliverable report.

C.2 Reliability Report

The report shall include the following:

1. A written functional description of the EPCU with appropriate diagrams.

2. Description of reliability model complete with reliability block diagrams and equations.

3. Fundamental assumptions and/or rules that were applied in the reliability study.

4. Table of major components with failure rates. (Examples of major components include, FRPC, load converter module, 1553 interface, indicators, main switch, etc.)

5. Conclusions and Recommendations. (Follow-Up discussion shall be included in the CDR report).

APPENDIX D – FAILURE MODES AND EFFECTS ANALYSIS

D.1 Failure Modes and Effects Analysis (FMEA) and Critical Item List (CIL)

The contractor shall perform a FMEA on the design of the EPCU and shall derive a CIL from the FMEA. The requirement to perform an FMEA on the EPCU results from a flowdown of requirements from SSP 50431. (Space Station Requirements for Payloads) and the Standard Assurance Requirements and Guidelines for Experiments (SARGE)].

The FMEA shall consider the possible failure modes of the EPCU design and their effects starting at the major component level. Major components are defined in terms of examples such as the FRPCMs, load converter modules, 1553 interface, indicators, main switch, etc. The FMEA should list failure modes and their effects upon internal EPCU functions, and upon EPCU output. Brief explanations of failure causes should be given, along with criticality, detection capability, and corrective action. EPCU failure modes associated with missing output, incorrect or noisy output, late or intermittent response, should be considered within the analysis. An assumption of the failure modes and effects analysis of the EPCU should be that all necessary inputs to the EPCU are present and correct. (extracted from SSP 30234).

D.2 Ground Rules

All failure modes and effects are to be identified at the appropriate level of detail: major component, channel, and EPCU output.

The criticality categorization of a failure mode shall be made on the basis of the worst case potential failure effect.

Items exempt from analysis are tubing, mounting brackets, structure, electrical wiring, and electronic chassis enclosures.

Identical items which perform the same function, in the same environment (where the only difference is location) will be documented on the FMEA worksheet only once, provided that the failure modes are identical.

Criticality Categories: All failure modes shall be categorized according to the severity of their effects. The failure mode criticality categories defined for the FMEA on the EPCU shall be as follows:

1 - A single point failure that could result in serious injury or loss of life.

1R - Redundant hardware items, all of which failed, could result in serious injury or loss of life.

2 - A single point failure that could result in less than the required minimum power output from the EPCU.

2R - Redundant hardware items, all of which, if failed, could result in less than the required minimum power output from the EPCU.

3 - A failure that could result in a reduction of EPCU power output, for which, the power output of the EPCU does not fall below the required minimum.

D.3 Critical Items

A “Critical Item” screen is defined so as to -identify items (failure modes and their associated hardware device) whose failure effects are severe. Critical Items must be addressed either by re-design, or by a rationale to retain the item in the design. Rationale to retain an existing critical item in the design can be based on design features that will minimize risk, operational workarounds, Failure detection, Isolation, and Recovery capability (FDIR), performance testing, proven flight performance, or maintainability. A critical items list (CIL) shall be derived from the FMEA performed on the EPCU.

D.3.1 Critical Item Screen Definition:

An item is considered critical if it is a criticality 1,1R, or 2. Also an item is considered critical if failure of this item results in a state of the EPCU such that:

- Loss of EPCU output cannot be determined by flight or ground crew.
- Functional Status of EPCU cannot be determined.
- EPCU output can propagate an effect outside of its physical boundary and damage other flight hardware.

The contractor shall prepare a FMEA and CIL report which shall be deliverable to the government. The FMEA/CIL report shall be submitted 90 days following PDR. The contractor FMEA/CIL task for the EPCU is not complete until NASA GRC approves the report.

D.3.2 FMEA and CIL Report

The report shall detail any special assumptions made to facilitate the analysis, and shall present the entire CIL and FMEA. The retention rationale shall be submitted as part of the report, along with the system reliability block diagram, and a narrative which describes the functions and operation of the EPCU. A selected set of key diagrams, schematics, and engineering drawings, that were used to perform the analysis, shall be included in the analysis report to the government. The report shall begin with a technical summary for management which shall discuss the conclusions reached from the analysis and provide recommendations on the design or operation of the EPCU. The rows of item and failure mode information on FMEA worksheets should be listed by hardware devices and can be grouped under primary EPCU functions in a logical manner to facilitate review. Tables of critical items on the CIL should be grouped according to criticality categories. Within a criticality category, critical items should be listed by hardware device under EPCU functions in a logical manner to facilitate review.

The FMEA/CIL shall be a deliverable item to the Government, and provide the technical content defined above in the Contractor's standard format such that a Government Technical Writer can readily convert it into the required format, without applying knowledge of the engineering discipline of the content.

D.3.3 Summary of Required Data Elements

D.3.3.1 FMEA Data Elements

- Hardware component, device, or part descriptive title
- Part Number and Schematic/drawing reference
- Function : - An action or process performed by a sub-system or component by design, which usually involves the transfer of energy and may include the transfer of information.
  [Note: an alternative definition may apply to passive components of a system such as structure whose "function" is load bearing capability. Welds, brazings, and epoxy have a function which is to provide adhesion of parts when subjected to forces.]
- Failure Mode number: A number on the FMEA worksheet which identifies a particular hardware item, a specific failure mode, and the corresponding block on the EPCU reliability block diagram.

- Criticality category: The assigned category of a failure mode based upon the severity of its worst case effect which indicates if the failure mode is a single point failure or occurs from the failure of redundant devices.
- Local Effect: The consequences a failure mode has on the operation, function, or status of other items (within the EPCU) which interface with the specific item being analyzed.
- EPCU Level Effect: The consequence(s) a failure mode has on the operation, function, or status of the overall EPCU.
- Potential Effect on FCF/Crew: The possible consequences that a failure mode could have on the operation, function, or status of other FCF sub-systems, the FCF, or crew.
- Failure detection method: An identification of how a failure mode would be detected.
- Potential causes: A description [based on the best component information we have, or knowledge of the component design] of what could cause the failure mode indicated.
- Corrective action: Description of any short term or long term corrective action, automatic or manual, which is available to mitigate the effects of failure. For Short term corrective action this includes the identification of any alternative means of accomplishing the function performed by the item or its assembly. For long term corrective action, this includes isolating, and restoring the failed item. If none, or unknown, so indicate

D.3.3.2 CIL Data Elements

- Hardware component, device, or part descriptive title
- Part Number and reference to schematic or drawing
- Reference to FMEA worksheet
- Retention Rationale- If none state “None”.
- Design Features: Aspects or features of the design that have been included to reduce risk, specifically, to reduce the probability that the failure mode will occur or that the worst case effect will occur. (given the occurrence of the failure mode)
- Operational work-around: Any alternative path that can be used to maintain the function supported by the failed device.
- Testing and Inspection: specific tests or inspections planned to detect the onset of a condition, defects or anomalies that, if allowed to grow, would result in the occurrence of the failure mode.
- Previous flight success history: Information on the prior usage of the device technology or specific design type on other missions that demonstrates mission success and strengthens the rationale for retaining the device type in the current design.
- Maintainability: Preventative or corrective maintenance that can be performed to preclude or mitigate the effects of a failure mode.

D.4 Maintainability Analysis Report

A maintainability analysis report should be delivered to the government about 30 days after PDR which describes the simulated or trial installation of the EPCU and describes the design features provided which preclude the incorrect installation of the EPCU. The report should describe the results of the trial installation. It should also describe the actual results of a trial removal from the integrated payload system and show verification of successful and safe removal. Installation or removal difficulties should be described in the report. The contractor should indicate any changes needed to correct installation or removal problems. Particular attention should be given to the external connectors on the EPCU and their performance (adequacy) during the trial installation/removal.

APPENDIX E – QUALIFICATION COMPLIANCE MATRIX

TRS1129 describes the functional requirements that are verified on every EPCU. The validation data is shipped with every controller and is found in their respective data packages.

Legend:

1. Analysis
   (Includes Inspections/Demonstrations)
2. Test
   a. Development
   b. Qualification
   c. Acceptance

Requirement	Verification Method					Reference and Notes Qual Report (AER4988/X), ATP Paragraph Number NA = NOT APPLICABLE VSR = Verified by Subsequent Requirement
	NA	1	2			
			a	b	c	
1 PURPOSE	X					NA
1.2 SCOPE						NA
2 REFERENCES	X					NA
2.1 APPLICABLE DOCUMENTS	X					NA
2.2 REFERENCE DOCUMENTS	X					NA
2.3 PRECEDENCE	X					NA
2.4 ACRONYM	X					NA
3 REQUIREMENTS	X					Title
3.1 EPCU DEFINITION	X					VSR 3.1.1
3.1.1 INTERFACE DEFINITION	X					VSR 3.1.1.1 – 3.1.1.4
3.1.1.1 ELECTRICAL	X					VSR para 3.2 & subs
3.1.1.2 MECHANICAL	X					VSR para 3.2 & subs
3.1.1.3 THERMAL	X					VSR para 3.2 & subs
3.1.1.4 DATA BUS INTERFACE	X					VSR para 3.2 & subs
3.2 CHARACTERISTICS	X					Title
3.2.1 PERFORMANCE CHARACTERISTICS	X					Title
3.2.1.1 ELECTRICAL POWER CHARACTERISTICS	X					VSR 3.2.1.2 – 3.2.1.26
3.2.1.2 STEADY STATE VOLTAGE CHARACTERISTICS	X					Title
3.2.1.2.1 INTERFACE B					X	/2-4.1.8
3.2.1.3 RIPPLE VOLTAGE CHARACTERISTICS	X					Title
3.2.1.3.1 RIPPLE VOLTAGE AND NOISE				X		/2-4.1.2
3.2.1.3.2 RIPPLE VOLTAGE SPECTRUM				X		/2-4.1.2
3.2.1.4 TRANSIENT VOLTAGES				X		/2-4.1.4 & /2-4.1.8
3.2.1.5 FAULT CLEARING AND PROTECTION				X		/2-4.1.4 /2-4.1.6 /5-4.3.1.3 (CS06) /8-4.3.1

Requirement	Verification Method					Reference and Notes Qual Report (AER4988/X), ATP Paragraph Number NA = NOT APPLICABLE VSR = Verified by Subsequent Requirement
	NA	1	2			
			a	b	c	
3.2.1.6 NON-NORMAL VOLTAGE RANGE				X		/8-4.3.2
3.2.1.7 Blank	X					Title
3.2.1.8 POWER BUS ISOLATION		X		X		/8-4.3.3
3.2.1.9 COMPATABILITY WITH SOFT START/STOP RPC				X		/2-4.1.1
3.2.1.10 SURGE CURRENT				X		/2-4.1.1
3.2.1.11 REVERSE ENERGY/ CURRENT		X		X		/1-3.1.1 /2-4.1.7
3.2.1.12 REMOTE POWER CONTROLLERS (RPCs)		X		X		/2-4.1.1
3.2.1.13 RPC TRIP COORDINATION	X					Title
3.2.1.13.1 PAYLOAD TRIP RATINGS		X				/1-3.1.2
3.2.1.14 EPCU Input IMPEDANCES	X					Title
3.2.1.14.1 INTERFACE B				X		/2-4.1.3
3.2.1.15 LARGE SIGNAL STABILITY				X		/2-4.1.5
3.2.1.16 MAXIMUM RIPPLE VOLTAGE EMISSIONS				X		/2-4.1.2
3.2.1.17 ELECTRICAL LOAD-STAND ALONE STABILITY		X				/1-3.1.3
3.2.1.18 EPCU Output Characteristics	X					Title
3.2.1.18.1 WIRE DERATING		X				/1-3.1.4
3.2.1.18.2 LOSS OF POWER		X				/1-3.1.5
3.2.1.18.3 EPCU USER PARAMETERS		X				/1-3.1.6
3.2.1.18.4 POWER QUALITY	X					Title
3.2.1.18.4.1 Output VOLTAGE RANGE		X			X	/1-3.1.7
3.2.1.18.4.2 RIPPLE				X		/8-4.3.4
3.2.1.18.4.3 TRANSIENTS					X	TRS1129
3.2.1.18.4.4 CURRENT LIMITING AND TRIP FUNCTION					X	TRS1129
3.2.1.18.4.5 PARALLEL OPERATION					X	TRS1129
3.2.1.18.4.6 REMOTE TRIP FUNCTION					X	TRS1129
3.2.1.18.4.7 INITIAL POSITION					X	TRS1129
3.2.1.19 HEALTH MONITORING SENSOR DATA		X				/1-3.1.8
3.2.1.20 EPCU INTERNAL SENSORS					X	TRS1129
3.2.1.21 FUNCTIONAL PERFORMANCE		X			X	/1-3.1.9, TRS1129
3.2.1.22 LOAD SHEDDING					X	TRS1129
3.2.1.23 FAILURE DETECTION, ISOLATION, AND RECOVERY		X				/1-3.1.10, TRS1129, /2-4.1.4, 4.1.6, 4.1.8, 4.3.1, 4.3.2, AND /5-4.3.1.3
3.2.1.24 CONVERTER CHARACTERISTICS				X		/8-4.3.4
3.2.1.25 SOLID STATE CURRENT LIMIT SWITCH (REMOTE POWER CONTROLLER RPC) Characteristics		X			X	/1-3.1.11

Requirement	Verification Method					Reference and Notes Qual Report (AER4988/X), ATP Paragraph Number NA = NOT APPLICABLE VSR = Verified by Subsequent Requirement
	NA	1	2			
			a	b	c	
3.2.1.26 FRONT PANEL INDICATORS		X				/1-3.1.12
3.2.1.26.1 POWER A					X	TRS1129
3.2.1.26.2 POWER B					X	TRS1129
3.2.1.26.3 RPC TRIP					X	TRS1129
3.2.2 PHYSICAL CHARACTERISTICS		X				/1-3.1.13
3.2.2.1 MASS		X		X		/1-3.1.14
3.2.2.2 ENVELOPE		X				/1-3.1.15
3.2.2.3 INTERFACE CHARACTERISTICS	X					Title
3.2.2.3.1 ELECTRICAL INTERFACE	X					Title
3.2.2.3.1.1 CONNECTORS		X				/1-3.1.16
3.2.2.3.2 MECHANICAL INTERFACE	X					Title
3.2.2.3.2.1 MOUNTING INTERFACE		X				/1-3.1.17
3.2.2.3.3 THERMAL INTERFACE	X					Title
3.2.2.3.3.1 THERMAL MANAGEMENT SYSTEM		X		X		/4 and drawing number 771131
3.2.2.3.3.2 COOLANT OUTLET TEMPERATURE				X		/4
3.2.2.3.3.3 HEAT REJECTION TO THERMAL CONTROL SYSTEM (TCS)		X		X		/4
3.2.2.3.3.4 COOLING FLUID		X				Drawing number 771133 note 6 and 771145 note 6
3.2.2.3.3.5 PRESSURE DROP				X		/4
3.2.2.3.3.6 COOLANT MAXIMUM OPERATING PRESSURE		X				/1-4.0
3.2.2.3.3.7 PROOF PRESSURE					X	TRS1129
3.2.2.3.3.8 LEAKAGE RATE					X	TRS1129
3.2.2.3.3.9 HEAT LOSS TO PRESSURIZED VOLUME		X				/1-3.1.18 /4
3.2.2.3.3.10 FLUID INTERFACE		X				/1-3.1.19
3.2.2.3.3.11 TOUCH TEMPERATURE				X		/4
3.2.2.3.3.12 BURST PRESSURE		X		X		/1-4.0
3.2.2.3.3.13 COOLING SYSTEM CLEANLINESS		X				/1-3.1.20 drawing number 771131
3.2.2.3.3.14 Fluids		X				drawing number 771131
3.2.2.3.4 DATA INTERFACE		X				VSR 3.2.2.3.4.1 – 3.2.2.3.4.11
3.2.2.3.4.1 EPCU COMMAND DATA INTERFACE CHARACTERISTICS		X				/1-3.1.21
3.2.2.3.4.2 RESTART COMMAND SEQUENCE WHILE IN THE IDLE STATE					X	TRS1129
3.2.2.3.4.3 RESTART COMMAND SEQUENCE WHEN NOT IN THE IDLE STATE					X	TRS1129
3.2.2.3.4.4 LOAD-EXCAVATE COMMAND SEQUENCE AND DATA VALIDATION					X	TRS1129
3.2.2.3.4.5 DISCRETE DATA					X	TRS1129

Requirement	Verification Method					Reference and Notes Qual Report (AER4988/X), ATP Paragraph Number NA = NOT APPLICABLE VSR = Verified by Subsequent Requirement
	NA	1	2			
			a	b	c	
3.2.2.3.4.6 ANALOG DATA					X	TRS1129
3.2.2.3.4.7 RAM TESTING					X	TRS1129
3.2.2.3.4.8 SUB-ADDRESS SEQUENCE FOR RAM TESTING					X	TRS1129
3.2.2.3.4.9 ALTERNATE RAM BLOCK SELECTION					X	TRS1129
3.2.2.3.4.10 ALTERNATE READ ONLY MEMORY (ROM) BLOCK SELECTION		X				FPGA Drawing numbers 771524 - A5_U16 1703011 - A11_U2 1703009 - A11_U1 771534 - A11_U8 1702759 - A12_U13 1702825 - A13_U13
3.2.2.3.4.11 NOTIFICATION OF EPCU RESET					X	TRS1129
3.2.3 RELIABILITY	X					Title
3.2.3.1 FAILURE TOLERANCE		X				/1-3.1.22
3.2.3.2 MTBF		X				/1-3.1.23
3.2.3.3 FAILURE PROPAGATION		X				/1-3.1.24
3.2.4 MAINTAINABILITY	X					Title
3.2.4.1 INCORRECT EQUIPMENT INSTALLATION		X				/1-3.1.25
3.2.4.2 EPCU MEAN MAINTENANCE CREW HOURS PER YEAR	X					Verified at the rack level
3.2.4.3 EPCU MEAN TIME TO REPAIR	X					NA
3.2.5 ENVIRONMENTAL CONDITIONS	X					Title
3.2.5.1 Deleted	X					DELETED
3.2.5.2 OPERATING TEMPERATURE					X	TRS1129
3.2.5.3 NON-OPERATING TEMPERATURE					X	TRS1129
3.2.5.4 OPERATING HUMIDITY		X				/1-3.1.26 This requirement was verified assuming a noncondensing environment.
3.2.5.5 NON-OPERATING HUMIDITY		X				/1-3.1.26
3.2.5.6 PRESSURE		X				/1-3.1.27
3.2.5.7 LAUNCH AND RETURN				X		VSR /3
3.2.5.8 IONIZING RADIATION LIMITS		X		X		/10 and /1
3.2.5.8.1 SINGLE EVENT (SEE) IONIZING RADIATION		X	X			/1-3.1.28 and /10 and development test Data
3.2.5.9 VIBRATION	X					Title
3.2.5.9.LOADS AND VIBRATION ENVIRONMENTS				X		/3
3.2.5.10 ACOUSTIC	X					Title
3.2.5.10.1 ASCENT ACOUSTIC ENVIRONMENTS				X		/3
3.2.5.10.2 ACOUSTIC EMISSION LIMITS				X		/6

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	NA	1	2			
			a	b	c	
3.2.5.11 ACCELERATION	X					Title
3.2.5.11.1 ON-ORBIT ACCELERATION ENVIRONMENT		X				/1-3.1.29
3.2.5.12 IVA LOADS		X				/1-3.1.30
3.2.6 TRANSPORTABILITY	X					Title
3.2.6.1 TRANSPORTABILITY PROVISIONS		X				/9
3.2.6.2 EARTH TO ORBIT TRANSPORTABILITY		X				/9
3.2.6.3 SHIPPING, HANDLING, AND STORAGE		X				/9
3.2.6.4 TRANSPORTATION AND HANDLING ACCELERATIONS		X				/9
3.3 DESIGN AND CONSTRUCTION		X				RM-1097B
3.3.1 MATERIALS, PROCESSES, AND PARTS		X				/1-3.1.31 MIUL letter #MSU-NAD-02/08/01
3.3.1.1 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS		X				/1-3.1.32
3.3.1.1.1 EEE PARTS TRACEABILITY		X				/1-3.1.33
3.3.2 ELECTROMAGNETIC COMPATABILITY	X					Title
3.3.2.1.1 ELECTRICAL GROUNDING		X	X			TS6519-3.3.2.1.1 and 3.3.2.1.1.1, /1-3.1.34
3.3.2.1.1.1 SINGLE POINT GROUND		X				/1-3.1.35
3.3.2.1.2 ELECTRICAL BONDING		X				/1-3.1.36
3.3.2.1.3 ELECTROMAGNETIC INTERFERENCE				X		/2-4.1.1
3.3.2.1.4 ELECTROSTATIC DISCHARGE		X				/1-3.1.37
3.3.2.1.5 ALTERNATING CURRENT (AC) MAGNETIC FIELDS				X		/5-4.3.1.4
3.3.2.1.6 DIRECT CURRENT (DC) MAGNETIC FIELDS				X		/5-4.3.1.11
3.3.2.1.7 EMI SUSCEPTIBILITY FOR SAFETY CRITICAL CIRCUITS	X					NA
3.3.3 NAMEPLATES AND PRODUCT MARKING	X					Title
3.3.3.1.1 PRODUCT MARKING FOR GROUND ASSEMBLY AND HANDLING		X				771125
3.3.3.1.2 LABELING		X				/1-3.1.38
3.3.3.1.3 OPERATING INSTRUCTIONS	X					NA
3.3.3.1.4 CAUTION AND WARNING LABELS		X				/1-3.1.39
3.3.4 WORKMANSHIP		X				EPCU-PA1 Revision c
3.3.4.1.1 CLEANLINESS		X				/1-3.1.40

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	NA	1	2			
			a	b	c	
3.3.4.1.2 CLEANLINESS OF SURFACES IN CONTACT WITH FLUIDS		X				/1-3.1.41
3.3.4.1.3 INTERNAL SURFACES		X				/1-3.1.41
3.3.4.1.4 PACKAGING DESIGNS		X				/1-3.1.41
3.3.4.1.5 FUNGUS RESISTANT MATERIAL		X				/1-3.1.42
3.3.4.1.6 BURN-IN TESTING					X	TRS1129
3.3.5 INTERCHANGEABILITY	X					Title
3.3.5.1.1 INTRA-RACK INTERCHANGEABILITY	X					NA
3.3.5.1.2 INTER-RACK INTERCHANGEABILITY	X					NA
3.3.6 SAFETY	X					Title
3.3.6.1 GENERAL		X				/1-3.1.43
3.3.6.2 PAYLOAD ELECTRICAL SAFETY		X				/1-3.1.44
3.3.6.3 MATING/DEMATING OF POWERED CONNECTORS		X				/1-3.1.45
3.3.6.4 BENT PIN OR CONDUCTIVE CONTAMINATION		X				/1-3.1.46
3.3.6.5 FIRE PROTECTION		X				/1-3.1.47
3.3.6.5.1 FIRE PREVENTION		X				/1-3.1.48
3.3.6.6 AUTOMATIC RESTARTING PROTECTION					X	TRS1129
3.3.6.7 PRESSURIZED VOLUME DEPRESSURIZATION/ REPRESSURIZATION		X				/9 /1-3.1.27
3.3.6.8 OPERATION DURING PRESSURE CHANGES		X				/9 /1-3.1.27
3.3.6.9 COMPONENT HAZARDOUS ENERGY PROVISION		X				/1-3.1.49
3.3.6.10 HUMAN ENGINEERING SAFETY	X					Title
3.3.6.10.1 INTERNAL CORNER AND EDGE PROTECTION		X				/1-3.1.50
3.3.6.10.2 LATCHES	X					NA EPCU design does not incorporate latches
3.3.6.10.3 SCREWS AND BOLTS	X					NA EPCU design does not incorporate exposed screw or bolt threads
3.3.6.10.4 SAFETY CRITICAL FASTENERS		X				/1-3.1.51
3.3.6.10.5 LEVERS, CRANKS, HOOKS, AND CONTROLS	X					NA
3.3.6.10.6 HANDLES (Captive Parts)	X					NA
3.3.6.10.7 SECURING PINS	X					NA
3.3.6.10.8 BURRS		X				/1-3.1.52

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	NA	1	2			
			a	b	c	
3.3.6.10.9 HOLES		X				/1-3.1.53
3.3.6.10.10 LOCKING WIRES	X					NA
3.3.6.10.11 TOUCH TEMPERATURE				X		/4
3.3.6.10.12 OFFGASSING				X		/7
3.3.6.10.13 SAFE WITHOUT SPACE SHUTTLE/ISS PROGRAM SERVICES		X				/1-3.1.54
3.3.6.10.14 IGNITION OF ADJACENT MATERIALS				X		/4
3.3.6.10.15 ACCIDENTAL CONTACT WITH ELECTRICAL EQUIPMENT		x				VSR paragraphs 3.1.18.3
3.3.6.10.16 SAFETY CRITICAL CIRCUITS REDUNDANCY		X				/1-3.1.55
3.3.6.10.16.1 SAFETY-CRITICAL STRUCTURE		X				/1-3.1.56
3.3.6.10.17 HAZARD DETECTION AND SAFING		X		X		/1-3.1.57
3.3.6.10.18 EPCU OUTPUT OVER-VOLTAGE AND UNDER-VOLTAGE PROTECTION		X				/1-3.1.58
3.3.6.10.19 COMMAND AND COMPUTER CONTROL OF HAZARDOUS FUNCTIONS		X			X	/1-3.1.59
3.3.6.10.20 EPCU ON/OFF INHIBIT SWITCH INTERFACE	X					Verify at rack level
3.3.6.10.21 HAZARDOUS MATERIALS		X		X		/7 EPCU heat exchanger is leak and proof tested to contain DI water. Dwg 771131
3.3.7 HUMAN PERFORMANCE/ HUMAN ENGINEERING	X					Title
3.3.7.1.1 ACTUATED CONTROLS					X	TRS1129
3.3.7.1.2 HOUSEKEEPING		X				/1-3.1.60
3.3.7.1.3 TEMPORARY STORAGE ENVELOPE	X					NA
3.3.8 STANDARDS OF MANUFACTURE		X				/1-3.1.61
3.4 QUALIFICATION (FIRST ARTICLE)		X				/1-3.1.62
3.5 STANDARD SAMPLE		X				/1-3.1.63
5 PREPARATION FOR DELIVERY	X					NA
5.1 GENERAL	X					NA
5.2 PACKAGING, HANDLING, AND TRANSPORTATION	X					NA
APPENDIX C RELIABILITY ANALYSIS		X				RM1097B